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Use of optical storage devices as shared resources in Local Area Networks

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

USE OF OPTICAL STORAGE DEVICES
AS SHARED RESOURCES
IN LOCAL AREA NETWORKS

by

James Claude Hoge

September, 1989

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Since the start of the computer era, information users have been restricted by inadequate and expensive data storage. The development of solid state memory, soft storage media (floppy disk drives), drum memory drives and fixed disk drive mechanisms have improved data storage and retrieval, reducing the cost of information to under $10 per megabyte for large storage devices. The introduction of laser technology and the development of optical data storage now makes tremendous amounts of data available to users. Optical disk drives can be accessed as peripheral devices by most stand alone microcomputers at a cost of less than $.30 per megabyte of information. Although the cost per megabyte is low, the cost per work station can run $1,500 to $2,500 (or more) per year. Optical storage devices and the data bases released in optical format can be:

(1) too expensive for addition to individual workstations or
(2) under utilized in a single user environment or
(3) difficult to manage when two or more users share a single work station.

Current networking strategies have the potential to reduce data costs even more by allowing data storage devices to be shared by multiple users. This study evaluates the possibility of combining optical storage technology with the data sharing properties of a Local Area Network (LAN) to solve these three problems.

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Use of Optical Storage Devices as Shared Resources In Local Area Networks

by

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Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

Since the start of the computer era, information users have been restricted by inadequate and expensive data storage. The development of solid state memory, soft storage media (floppy disk drives), drum memory drives and fixed disk drive mechanisms have improved data storage and retrieval, reducing the cost of information to under $10 per megabyte for large storage devices. The introduction of laser technology and the development of optical data storage now makes tremendous amounts of data available to users. Optical disc drives can be accessed as peripheral devices by most stand alone micro-computers at a cost of less than $.30 per megabyte of information. Although the cost per megabyte is low, the cost per work station can run $1,500 to $2,500 (or more) per year. Optical storage devices and the data bases released in optical format can be:

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I. INTRODUCTION

A. BACKGROUND

Since the start of the computer era, computer users have been restricted by inadequate and expensive data storage. The development of solid state memory, soft storage media (floppy disk drives), drum memory drives and fixed disk drive mechanisms have improved data storage and retrieval, reducing the cost of information to just under $10 per megabyte for large storage devices. Current networking strategies have reduced data costs even further by allowing data storage devices to be shared by multiple users.

Laser technology and the introduction of optical data storage now makes tremendous amounts of data (up to 3.2 gigabytes per disc) available to users. Optical disc drives can be used as peripheral devices by most micro-computer systems at a cost of less than $3.00 per megabyte of storage space. A number of recorded optical disks are now available commercially with a retail cost of $200 to $2,000 per disc ($.31 to $3.13 per megabyte of data).

The vast amounts of data made available on optical storage media are being utilized by single users. Even though the cost per megabyte is low, the cost per work station can run $1,500 to $2,500 per year (or more see Appendix 1). There are several problems associated with attaching optical storage devices to individual workstations.

- Optical storage devices are too expensive for addition to individual work stations

- Optical storage devices are under utilized in a single user environment

- It is difficult to manage access to optical storage when two or more users share a single work station.

B. USES OF OPTICAL STORAGE DEVICES

The U.S. Navy has often been a leader in the use of new and innovative technologies. Many more Department of the Navy (DON) projects exist but the following is a representative sample of the use of optical storage within the DON:

- The Paperless Ship Initiative requires that gigabytes of information be available on-line to support a ship's administration, maintenance, equipment repair and ship operations. The text requirements for equipment maintenance alone are measured in the hundreds of megabytes[1]. The addition of ships diagrams and schematics (assuming graphic resolution of approximately 80 dots per inch) would increase this storage requirement by a factor of ten or more. Successful development without optical storage (or some other technology with similar capabilities) would require expensive (and vulnerable) mass storage on fixed media.

- Naval Postgraduate School, Monterey has done extensive research in the storage of hard copy data records in a retrievable format on compact disc. As part of this development, three

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[1] This figure was derived assuming minimal maintenance manuals for a small combatant. This is 800 technical manuals averaging 100 pages of text with 55 lines per page and 72 characters per line (more than 316 megabytes). This figure is conservative and is included to indicate the order of magnitude of information which has to be available for access at any one time.

months of physical transactions for Naval Supply Center, Oakland were compiled and stored in a retrievable format on one compact disc. This program is referred to as Transaction Ledger on Compact Disc or TLOCD. [Ref. 1]

- Ship class configuration files have been saved to compact disc by several class managers. This makes all configuration information available to maintenance management personnel and is invaluable during ship overhaul and baseline configuration management reviews.

Other beneficial uses include:

- Management List Consolidated (MLC) information for all stock material used by the department of defense including past usage history, manufacturers information and illustrated guides are being distributed by several vendors. This information increases the chance that maintenance personnel will identify and purchase the correct material for shipboard repairs.

- The Navy has adopted ADA as a language standard for future development. Vendors are publishing ADA source code libraries on compact disc which can be accessed and used by any developer.

All of these uses point out the value of stored, indexed and addressable data and each one taken alone can yield a significant improvement in personnel productivity but each is designed to be accessed by one workstation (with the exception of the paperless ship initiative which will rely upon SAFENET, see Section III.H.1.a for additional information). There are many other potential uses with the number of available CD-ROM databases alone numbering more than 200. The value of each of these products can be increased if the information can be easily addressed from a single file server on a Local Area Network (LAN).

Magnetic media has been in use for many years and optical storage is introduced in this thesis as an augmenting storage medium. It is doubtful that fixed and floppy disks will be replaced by optical storage in the near future.. This paper addresses not only the benefits associated with optical storage but also some of the problems such as:

- WORM drives allow write access only.
- CD-ROM drives are usable only for accessing published material. They cannot be used for storage without an expensive process of pre-mastering and pressing [Ref. 1].
- Optical technology is new and its use may require additional personnel training costs which are not necessary with proven technology (magnetic media).
- Optical storage access times are slow when compared with large magnetic storage devices (on the order of 600 to 1000 milliseconds versus 11 to 30 milliseconds for magnetic)

C. THESIS METHODOLOGY

To understand the integration of LAN and optical storage technologies, it is necessary to investigate personal computer and software features. This thesis will provide pertinent background data in several different areas. The paper starts with an introduction to personal computers and installed hardware control features. A technical review of Microsoft DOS (MS-DOS) and the generation of device drivers will introduce the reader to external hardware control. Information concerning Microsoft Extensions version 2.10 will tie device control and CD-ROM players to a microcomputer. The following section covers theory and technical specifications of Local Area Networks followed by a short

description of several frequently found network topologies. A description of magnetic disk access through a LAN will provide a connection with the next section dealing with the various types of optical storage devices currently available. The discussion of optical storage devices centers primarily on CD-ROM technology which is more mature than either WORM or erasable optical storage device technology. The maturity can be directly attributed to adoption of International Standards Organization (ISO) standard 9660 which provides a formatting and storage standard for CD-ROM. A description of optical storage, search and retrieval methods will investigate the peculiarities of optical storage which impact upon LAN connection. The final sections deal with experiments conducted at Naval Postgraduate School Monterey, California and conclusions derived from research and experiments.

II. PERSONAL COMPUTERS

A. INTRODUCTION

To address the problems associated with connecting optical storage devices to LAN it is necessary to understand the installation and management of peripheral devices and personal computers (PCs). This section introduces PC operating systems, expandability and the connection of peripheral devices.

IBM Personal Computers and IBM compatible microcomputers (hereafter referred to as PCs) have become a de facto standard in the Department of the Navy. The first PCs were introduced by IBM eight years ago and many of these original micro-computers are still being used to support current software. One feature which has contributed significantly to the PC's longevity is its expandability which is based upon an open architecture. The original IBM PC was introduced as a mostly empty box containing a cpu and a number of slots for expansion cards. The phrase open architecture refers to these slots or ports which are available for the addition of input/output devices. The graphics adapter, monitor and keyboard which make up a minimum configuration stand alone microcomputer were optional I/O devices which had to be added as peripherals. The fact that the system was designed to support easy addition of peripheral devices extended its useful life by providing a flexible method for users to install (or upgrade) to match the latest technology.

An additional feature which has encouraged development of expansion capabilities and peripheral devices is direct memory access (DMA).

B. DIRECT CONTROL OF I/O PORTS

Programs have several methods of controlling devices. It is possible for a program to provide direct control over a device using direct I/O port access or calls to either the ROM-BIOS or MS-DOS services. As introduced earlier the I/O ports are the points of interface between the central processing unit (cpu) and peripherals or device controllers. The maximum (or logical) number of expansion ports is the same as the number of discrete addresses reserved for I/O on the bus (or 65,536 I/O ports) as defined for the Intel 8086 family of processors (including 8086, 8088, 80286 and 80386). Each of these I/O ports is directly attached to the address and data buses in the same manner as RAM memory. For the CPU to send (transfer) data to (or from) a device it sends out the address of the port on the address bus. The cpu then transfers information in digital form which will be received by the device (or controller) monitoring that specific address. When control signals are sent directly by the program there can be significant limitations. Because the program is directly controlling the device, it (program) has to know the addresses being monitored by that peripheral (or the logical name assigned by MS-DOS) and what specific instructions can be processed by that peripheral. This technique is used by many communication programs which rely upon Hayes compatible modems. The Hayes modem is a de-facto standard and

has been widely accepted by the micro-computer industry. Optical storage devices have no similar hardware standard and most programs accessing optical devices use a different control method.

C. PC CONTROL METHODS

All input/output (I/O) devices require some type of management to govern the movement of signals or data. This management (or control) can come from the computer's central processing unit (CPU) or it can come from the hardware device itself (using DMA). The micro-computer expansion ports mentioned above provide a control path. They establish an electrical connection to the computer circuitry via a hardware bus. The hardware which is attached to (inserted into) these expansion ports (or slots) must have some means of sending and receiving information and signals from the CPU. To facilitate this, there is a 64 kilo-byte block of addresses reserved for the peripherals connected to the bus. Each installed device is set to monitor a portion of this address space and each hardware pinout for that device can receive signals which are directed to it. These connections can be used to pass micro coded instructions, transistor bias signals or most any other digital signal. Most control cards have a device enable circuit which is triggered upon receipt of a specific memory address. This hardware constantly monitors the bus to determine if the installed device is being called upon by the CPU to perform some action. When a device finds a signal that is directed to its address space, the card is enabled and it can receive that information. Different pieces of information (or instructions) can then trigger different actions in the

addressed device. These actions can: direct a disk controller to extract information from a disk; direct a stream of instructions and text to a printer; or establish a data connection using an attached modem to name a few of the more popular uses of peripheral devices. One potential drawback to this control method is that if more than one device is monitoring the same address space then two (or more) devices may respond to the same signal causing unusual (possibly even destructive) results. An example of this occurred connecting a CD-ROM and WORM drive to a PC. Both devices had hardware control cards which had a default monitored address space of 300 (hex). When the devices were installed, signals directed to one (or the other device) would be passed to both simultaneously leading to inaccurate responses to drive access signals. Most expansion circuit cards designed for the bus slots have dip switches which allow the user to shift or modify the monitored address space. A simple dip switch adjustment and an address space parameter change during device initialization were sufficient to eliminate this contention.

1. ROM-BIOS and MS-DOS

To understand how DMA and device controllers are used to control access to an optical storage device (or indeed any I/O device), it is necessary to understand how control signals are sent to the hardware device and what role the PC operating system plays. IBM PC and PC compatible micro computers have a set of basic instructions which are contained in **R**ead **O**nly **M**emory (ROM). The ROM containing these instructions is referred to as the **B**asic **I**nput **O**utput **S**ystem or ROM-BIOS.

The ROM-BIOS provides basic instructions and directions required to access standard devices (these low level actions which can be directed to I/O devices will be referred to as primitive instruction groups). These primitive instruction groups include keyboard, video, disk, serial port, and printer services. ROM-BIOS instructions are, as the name implies, basic and do not organize data, nor can they provide the functionality required to access a non standard storage device (such as a CD-ROM player) without additional guidance. The additional guidance is partially provided by the **D**isk **O**perating **S**ystem (or DOS). The DOS provides high level processing capabilities and will either make calls to the ROM-BIOS or in the case of a standard attached device (such as magnetic disk drives), pass instructions directly to the software which controls an installed device. DOS also has several other features [Ref. 2].

- DOS organizes data into files or other useful data structures
- DOS performs limited error checking to verify accurate data reads and writes
- DOS uses the BIOS for device access and control by adding an additional layer between the program and the BIOS and allows programmers to work with a higher level instruction set.

The DOS which is most frequently used for PC and PC compatible micro-computers was developed by MicroSoft and is referred to as MS-DOS throughout this thesis.

2. Interrupts

Other methods of controlling a peripheral device include the use of hardware or software interrupts. An interrupt is a signal to the CPU or

device that an action is required (or has occurred) which requires the CPU's (or device controller's) attention. Hardware interrupts are generated by a physical action (e.g., keyboard key press, movement of a mouse, use of a light pen). Software interrupts are initiated by the operating system or application system when it has to access a peripheral device, pause execution, interrupt a process or perform any I/O task.

The ROM-BIOS is accessed by interrupts and provides video I/O, disk, serial port, keyboard, printer and time of day services as well as configuration checks. These services were identified and became part of the PCs ROM when it was originally released. The ROM-BIOS features, while powerful, are limited (for example the ROM-BIOS has instructions for reading and writing to a magnetic disk but has no features for grouping the data into files). If these services were the only ones that could be used for accessing peripherals then the PC's expandability would be extremely limited. To increase the flexibility of the ROM-BIOS, MS-DOS has reserved an additional 32 interrupts for operating system specific actions (see Table 1). The most commonly used interrupt for magnetic disk management is interrupt 21h. All requested system service calls are made through this interrupt (see Table 2). A later section explains how these service calls are used to support MS-DOS based LAN and how an extension of these calls is used to access CD-ROM players. Additional system service calls have been provided by Microsoft extensions (see Section VI.D.3.c and Table 3) to allow programmers to easily take advantage of the ISO 9660 or High Sierra standard (discussion of this standard is included in Section V.B.1)

disc format. Table 4 provides a listing of MS-DOS primitive groups with and without the MS-DOS CD-ROM extensions installed. Other interrupts which are important for connecting devices to a LAN include Interrupt 25H (absolute disk read interrupt) which is used to access the File Allocation Table (FAT, described in Section IV.E.1) and the boot record on magnetic disk drives and Interrupt 26h (absolute disk write interrupt) which can be used to write information to the FAT. The specific actions which occur as a result of interrupt calls are referred to as control primitives. It is the correct use of these primitives that makes peripheral device control possible.

TABLE 1. DOS INTERRUPTS

DOS Interrupts

20h	terminate program
21h	function call
22h	terminate address
23h	CTRL/break exit address
24h	vector for fatal error
25h	absolute disk read
26h	absolute disk write
27h	terminate but stay resident
28h-3fh	reserved

Note that the last 24 interrupts (28h through 3Fh) are reserved for used by DOS

Source: Writing MS-DOS Device Drivers, p. 31, Addison-Wesley Publishing Co, 1987.

TABLE 2. INTERRUPT 21 FUNCTION CALLS

*Interrupt 21h Function Calls

D	Disk reset
E	Select disk
F	Open file
10	Close file
11	Search for 1st entry
12	Search for next entry
13	Delete file
14	Sequential read
15	Sequential write
16	Create file
17	Rename file
19	Current disk
1A	Set disk transfer address
21	Random read
22	Random write
23	File size
24	Set relative record
25	Set vector

* Only mass storage control interrupts

Source: Writing MS-DOS Device Drivers, pp. 34-35, Addison-Wesley Publishing Co, 1987.

TABLE 3. SERVICE CALLS FOR MS-DOS CD-ROM EXTENSIONS

Service Calls for MS-DOS CD ROM Extensions

00	Get number of CD-ROM drive letters
01	Get CD-ROM drive device list
02	Get copyright file name
03	Get abstract file name
04	Get bibliographic doc file name
05	Read VTOC
06	Turn debugging on
07	Turn debugging off
08	Absolute disk read
09	Absolute disk write
0A	Reserved
0B	CD-ROM drive check
0C	MSCDEX version
0D	Get CD-ROM drive letters
0E	Get/Set volume descriptor preference
0F	Get directory entry
10	Send device request
11 - OFF	Reserved

Source: Microsoft MS-DOS CD-ROM Extensions Function Requests Specifications, p. 1, March 1989

TABLE 4. MS-DOS PRIMITIVE GROUPS

Primitive Groups for MS-DOS and MS-DOS CD-ROM extensions

	MS DOS	Primitive Number		MS-DOS Extensions
	Initialization	0	*	Initialization
	Media Check (block device)	1		Media Check (block devices)
	Get BIOS Parameter Block (block device)	2		Build BPB (block devices)
	IOCTL Input	3	*	IOCTL Input
	Input	4		Input(read)
	Nondestructive Input (char device)	5		Nondestructive Input No Wait
	Input Status (char device)	6		Input Status
	Input Flush (char device)	7	*	Input Flush
	Output	8		Output(write)
	Output with Verify	9		Output With Verify
	Output Status (char device)	10		Output Status
	Output Flush (char device)	11	#	Output Flush
	IOCTL Output	12	*	IOCTL Output
•	Device Open	13	*	Device Open
•	Device Close	14	*	Device Close
•	Removable Media (block device)	15		Removable Media (block devices)
•	Output Til Busy (char device)	16		Output Til Busy
••	Generic IOCTL (block device)	19		
••	Get Logical Device (block device)	23		
••	Set Logical Device (block device)	24		
		128	*	Read Long
		129		Reserved
		130	*	Read Long Prefetch
		131	*	Seek
		132	+	Play Audio
		133	+	Stop Audio
		134	#	Write Long
		135	#	Write Long Verify
		136	+	Resume Audio

KEY

- • DOS verision 3+ only
- •• DOS version 3.2+ only
- * Required for basic CD-ROM driver
- + extended CD_ROM driver
- # Erasable CD-ROM drivers

Source: Microsoft MS-DOS CD-ROM Extensions Device Driver Specifications, p. 7, March 1989

D. PC DEVICE DRIVERS

Software interrupts, hardware interrupts and DOS commands are used to pass instructions to memory resident software routines which will in turn pass directions to the peripheral device (or device controller). An example of this is a device driver. An interrupt could be issued which is vectored to a routine in the device driver. The sequence of events (Figure 1) which occurs upon user request to access a device include [Refs. 3 and 4]:

- An application requests I/O from an attached peripheral device and indicates which device is to be used (devices are called or referenced by name). MS-DOS issues an interrupt 21 call 0Fh which will open the device and treat it like an open file. (Step 1, Figure 1)

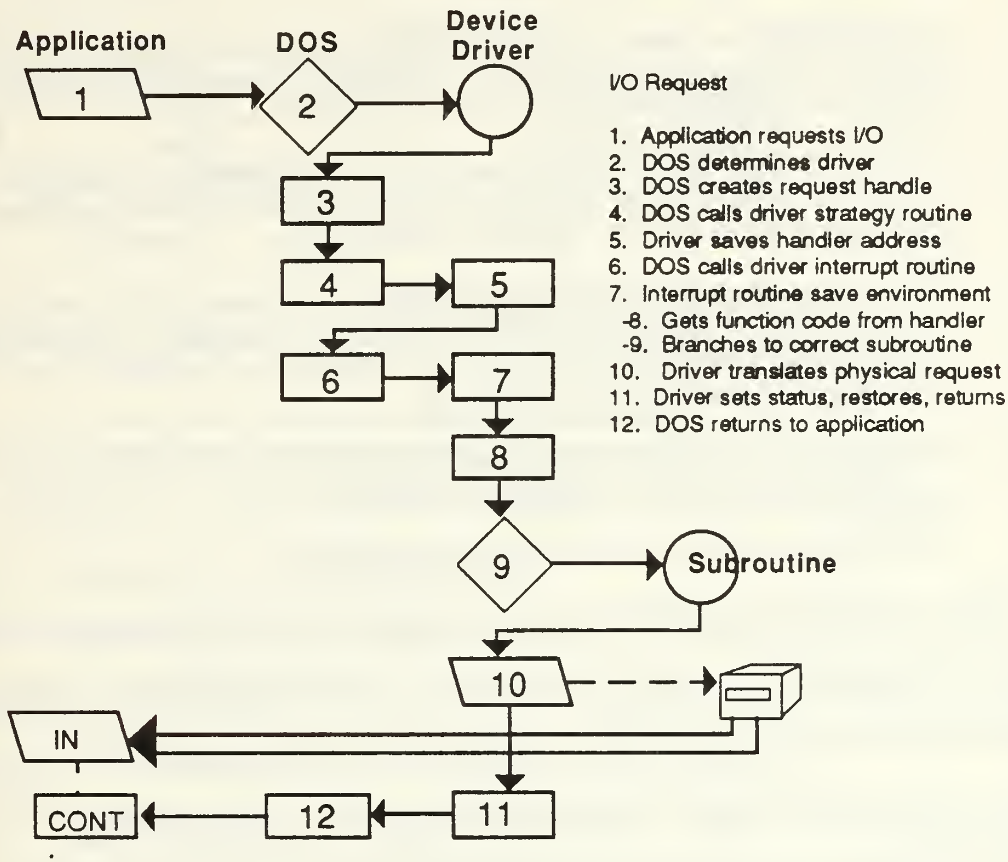
- MS-DOS sets up a File Control Block (FCB)[2]. This FCB is used to maintain status and data pertaining to the open file (device).

- MS-DOS determines which peripheral is to be accessed and locates the associated device driver.The device is then opened using the previously assigned device name (A - Z for mass storage devices). (Step 2)

- Each MS-DOS service request is translated to a standard set of rules (or primitive actions). MS-DOS then creates a request handle containing the data required to perform the requested I/O (primitive commands). When an application, hardware device or operating system accesses one of these device drivers MS-DOS automatically sets up the request header. This request header contains information necessary for access. (Step 3)

---

2 The number of blocks reserved by MS-DOS for file control is established using a *Files = XX* line within the config.sys start-up file.



Source: The Brady Guide to CD-ROM, p.74, Prentice Hall Press, 1987.

Figure 1. MS-DOS Peripheral Control

- MS-DOS calls the appropriate device drivers strategy routine. MS-DOS actually calls the device driver twice for each interrupt or function call. The strategy routine is designed to support multi-processing and the first call to the device driver routines serves only as a preliminary setup for the actions to be performed by the device driver. (Step 4)

- The appropriate device driver saves the request header address so the interrupt routine knows where to find the applicable instructions. (Step 5)

- MS-DOS now makes a second call to the device driver. This signals to the interrupt routine that the I/O request is ready to be acted upon by the device driver. (Step 6)

- The interrupt routine receives primitive instructions from the request handler and branches to the correct subroutines to act upon the instructions. (Steps 7 through 9)

- The driver subroutines generate the physical requests which are transmitted to the peripheral controller. If possible, the controller directs the external peripheral to perform the desired I/O and monitors its execution. (Step 10)

- When the I/O request has been completed, the driver returns control to MS-DOS. (Steps 11 and 12)

- MS-DOS returns control to the application.

Each manufacturer determines what features a device will have as well as what signals are required to control it, thus the software routines which are accessed through the device driver are not common to all devices. Each device has a unique set of routines. This combination of software routines used to control a peripheral device is found within the device driver. MS-DOS services (initiated by interrupt 21 calls) can be quite complex but will be translated to a series of DOS primitive groups (shown in Figure 2) appropriate to satisfy that service request.

Programs that use MS-DOS services for device access will have to sacrifice some speed because of the intermediate step of translating the service calls into DOS primitives, but in return gain flexibility and are more easily ported to other systems.

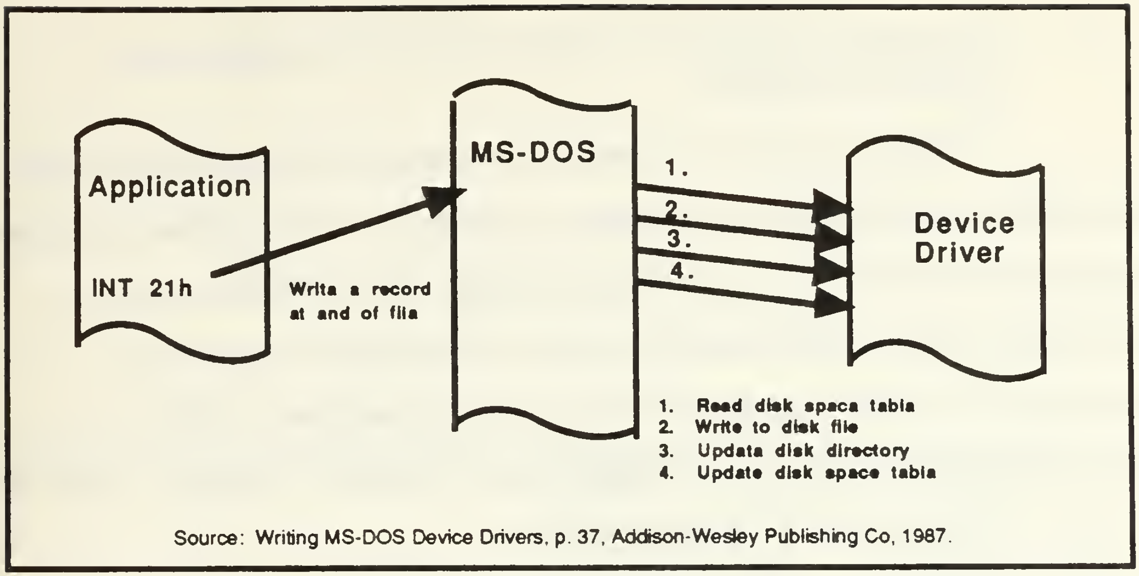


Figure 2. Service Call Translation to DOS Primitives

1. Structure of Device Drivers

Device drivers and their functions have been introduced, but what are device drivers and how do they translate primitive instructions into a language recognized by the peripheral device controller?

Device drivers are designed to reside in RAM with MS-DOS and have a standard structure. This structure is comprised of:

- A device header includes the name of the driver and a pointer to the next driver (linked list).
- A data storage and local procedure section contains local data variables, local routines and procedures.
- A strategy procedure contains routines used to set up calls to the device.
- An interrupt procedure contains the actual commands to be executed.

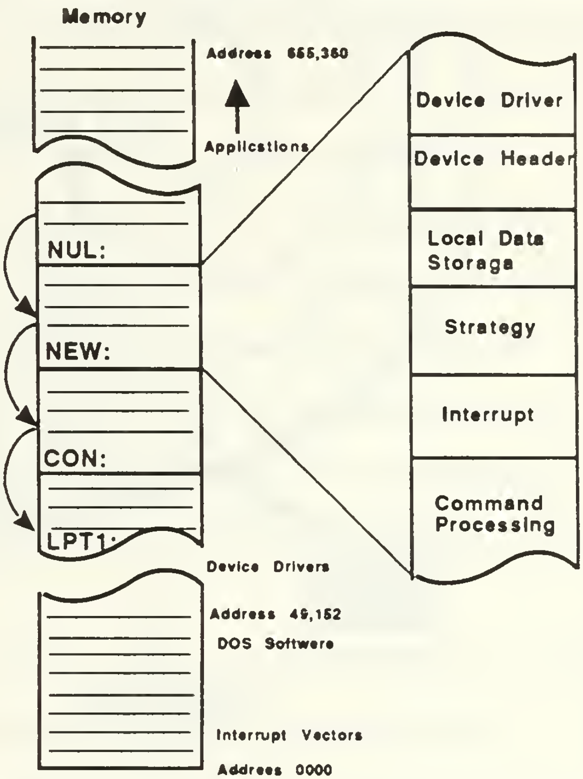
- Command processing routines which can be called by the interrupt procedure.

Control is passed to software routines by the interrupt instruction. Before this interrupt can be processed the address of the software routines must be stored in the interrupt vector address. Each interrupt has an associated vector in the low order memory of the cpu. This vector is comprised of 4 bytes and contains the offset and segment address to which the routine vectors when the interrupt instruction is issued. [Ref. 5]

2. PC Control of Device Drivers

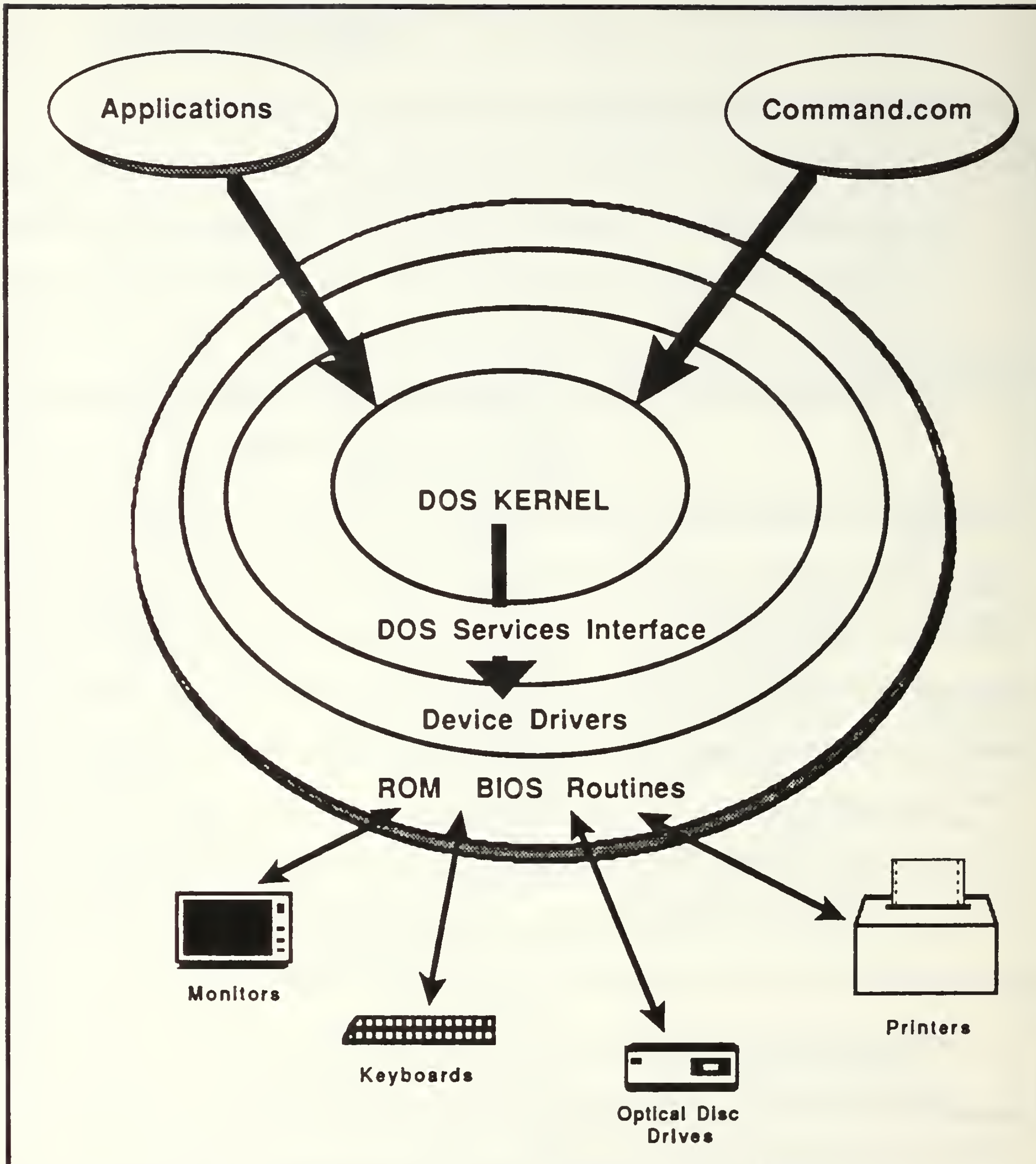
Software routines which control peripheral devices are referred to as device drivers. As introduced earlier, software routines which make up a device driver actually become part of the memory resident portion of MS-DOS. Their function is to react to MS-DOS primitives and convert them into instructions which will be recognized by a specific peripheral or device controller. Because these programs are written to Microsoft design specifications, MS-DOS can recognize new devices and can integrate them with the rest of its standard devices (Figure 3). It is within these routines that the calls to the ROM-BIOS code for the respective devices are executed. Device drivers (as defined within MS-DOS) are part of the MS-DOS kernel. They provide a standard interface to the device from within this kernel. Each device driver controls a device and uses the PC's BIOS routines (see Figure 4). Each device is assigned a reserved name and any reference to these reserved names will cause MS-DOS to access

DOS Device Name	Standard Device
con:	Kayboard/screen
com1:	Serial port #1
aux:	Auxiliary port (identical to com1:)
com2:	Serial port #2
lpt1,2,3:	Printer port #1,#2,#3
prn:	Logical printer port (identical to lpt1:)
nul:	Null device
clock$	Software clock
A:	First diskette unit
B:	Second diskette unit
C:	Hard disk (normally)



Source: Writing MS-DOS Device Drivers, p. 29, 39, 50, Addison-Wesley Publishing Co, 1987.

Figure 3. MS-DOS Device Drivers



Source: Writing MS-DOS Device Drivers, p. 37, Addison-Wesley Publishing Co, 1987.

Figure 4. MS-DOS/ROM-BIOS Interface

the appropriate device. These names include drive designations A through Z (used for accessing mass storage devices). As was mentioned

earlier, the original IBM PC was introduced as a box containing a cpu and a number of slots (or ports) for expansion cards. The graphics adapter, monitor and keyboard which make up a minimum stand alone microcomputer were all add-ons and each item had a device driver associated with it . MS-DOS maintains a linked list of device drivers starting with the "Null" device and ending with the MS-DOS provided device drivers for standard devices (con for the keyboard/monitor, com1 for the serial port etc.). When new device drivers are added they are added directly after the null device and before the last installed driver in a linked list. When a peripheral device is accessed by the operating system, a search is conducted from the "Null" device down this linked list. When the search finds the first device driver with the correct name, instructions are passed to this driver. This allows programmers to redefine or improve upon existing device drivers as well as providing a method for adding new drivers. The operating system is able to access new, replacement and standard device drivers simply by searching through this linked list.

3. Types of Devices

Peripheral devices are used as input/output (I/O) devices. There are two different types of I/O devices commonly found attached to microcomputers. Keyboards, numeric keypads and mice are examples of character oriented I/O devices which pass one piece of information and wait for a system response prior to passing the next piece of information. Magnetic disk drives and some optical storage devices on the other hand are considered to be block devices. Block devices manage groups of

characters and transfer a number of bytes or a "block" of information at a time (typically 512 bytes or a multiple of 512 bytes). These block devices are used for high speed data transfer. Block movement is used because fixed media and optical drives have disks which rotate at high speed; by the time one character has been transferred, the device is no longer in a position to read a second character. The block movement method allows the system to capture a block of data at a speed which is governed by the read (or write) access times. The speed of transmission and transmission medium determine data transfer rate per unit time but the rate of transfer is also affected by the block size (see Figure 5). A device with a large block size will spend less time performing administrative tasks and can yield a significantly higher data transfer rate than a device with a small block size operating at the same transmission speed. The drawback to this is that the larger the block size, the less precise the device. If a device with a block size of 1024 is asked to move 512 bytes, then The system would still transfer a complete block. The time required to transfer the excess 512 bytes is lost time and can slow down system operation. Additionally, the cost in memory buffer space is also directly affected by the block size. The larger the block size the larger the buffer required to support that block. This feature coupled with direct memory access (DMA), disk operating system and device drivers is what supports the addition of optical storage devices to PCs.

Computing Speed of Transmission

Movement of 2048 bytes of contiguous data

Given: speed of transmission 250 kbytes/second
seek time = 30 milliseconds
latency = 8 milliseconds

Example 1 Buffer Size 1024 bytes

Time to transfer = transmission time + seek time + latency time
= 2048 bytes/250 kbytes/second + (30 ms) + (8 ms * 2)
= 8 ms + 30 ms + 16 ms
= **54 ms**

Example 2 Buffer Size 512 bytes

Time to transfer = transmission time + seek time + latency time
= 2048 bytes/250 kbytes/second + (30 ms) + (8 ms * 4)
= 8ms + 30 ms + 32 ms
= **70 ms or 29.6% slower**

Figure 5. Data Transfer Rate Computations

The use of CD-ROM requires yet another type of device control. CD-ROM devices are neither character nor block devices but share traits with both. This is due to the continuous track storage feature of CD-ROM which is discussed more fully in Section IV.D.

4. Expansion Slots and Control Interface

One feature which has contributed to the longevity of the PC family of microcomputers is the expansion slots. One problem with expansion slots is that there is a limitation to the number of devices connected which is imposed by the physical size constraints of the computer chassis. Most PCs have installed (at a minimum) a printer

control card, a graphics card, a Winchester (or fixed) disk controller and a floppy disk control card. Add to this minimum configuration, network control cards, optical drive controllers, various interface cards for plotters, lab equipment, etc. and the number of available slots is insufficient. IBM has released an expansion chassis for the PC but this is an expensive alternative (both in terms of cost and space requirements). In addition, the expansion unit was used on the original PC because it had only five slots. With the advent of the XT, the number of slots was increased to eight.

Commercial vendors have released multi-purpose control cards to try to increase the expansion capability. This solution is an inflexible solution that forces users to constrain their expansion to available multi-purpose cards.

Another solution has been provided by the **S**mall **C**omputer **S**tandard **I**nterface (SCSI) as defined by the ANSI X3T9.2 committee. SCSI control cards can be installed in a PC expansion slot to provide expansion capability for an additional seven peripherals. Most mass storage devices (as well as many other peripherals requiring high speed data transfer) are now being released as SCSI devices. This implies that the actual controller resides within the peripheral and that it is physically connected to a SCSI port by cable. Each SCSI device is chained to the previous device (up to a total of seven devices) and only one SCSI card is required. The SCSI card acts as a bus extension and each SCSI device monitors a different address. Primitives sent by the device driver are

routed to the correct device so the operation is invisible to the user and to MS-DOS.

5. Summary

MS-DOS needs to know that the device driver is controlling some device, it must know the device name and the device driver must be capable of processing standard device driver commands. Without this uniform interface to MS-DOS, each manufacturer would have to supply its own custom version of MS-DOS with its device drivers or provide direct access from applications programs. This could cause incompatibility problems with different products.

III. LOCAL AREA NETWORKS

A. INTRODUCTION

> Local area network (LAN): A data communication network used to interconnect a community of digital devices distributed over a localized area of up to, say, 10 km^2. The devices may be office workstations, mini- and microcomputers, intelligent instrumentation equipment, etc. [Ref. 6]

A thorough understanding of Local Area Networks (LAN) is not required in order to share optical storage devices but the capabilities and restrictions associated with various LAN products and a general understanding of networking technology is required. This section will provide a basic understanding of LAN operating systems and topology. This information is necessary to understand the complexities and problems associated with using optical storage devices on LAN. This section concludes with a brief description of LAN topology as it applied to this thesis.

B. LAN OPERATING SYSTEMS VS MS-DOS

Network operating systems are a departure from the disk operating system (MS-DOS) being used on most Personal Computers. MS-DOS is designed to manage the operations of one computer and its associated peripherals. Network operating systems, however, deal with multitasking and multi-user environments and thus have more similarity to minicomputer and mainframe operating systems then to those being used

by most micro computers. MS-DOS (and early releases of OS/2) are designed to process sequential requests for disk or peripheral device access. In contrast to this, LAN Operating systems must be able to handle requests from a number of other activities (users). Obviously the LAN operating system must not only process each user request, it must also route services to the correct user. The network operating system acts as an arbitrator, servicing the various resources and users in the network. [Ref. 7]

C. LAN OPERATING SYSTEMS

A properly designed and implemented network should be invisible to the user. System operations, applications, use of print devices and mass storage systems should operate just as they would for a stand-alone computer. Unfortunately, the most frequently used operating system (MS-DOS) was designed and implemented before LANs became popular. MS-DOS, which has become a de-facto standard throughout the military was designed to support single application operation with relatively small mass storage devices (less than 32 megabyte maximum file size). The operating system has continued to evolve and although not a LAN operating system all MS-DOS releases after MS-DOS 3.1 have included utilities to allow sharing of peripheral devices across LANs. A number of available LANs use some sort of MS-DOS derived operating system but many popular LANs utilize their own operating systems. An example of this is Netware by Novell which accounts for more than 60% of installed PC networks (along with other Novell products). Those networking solutions

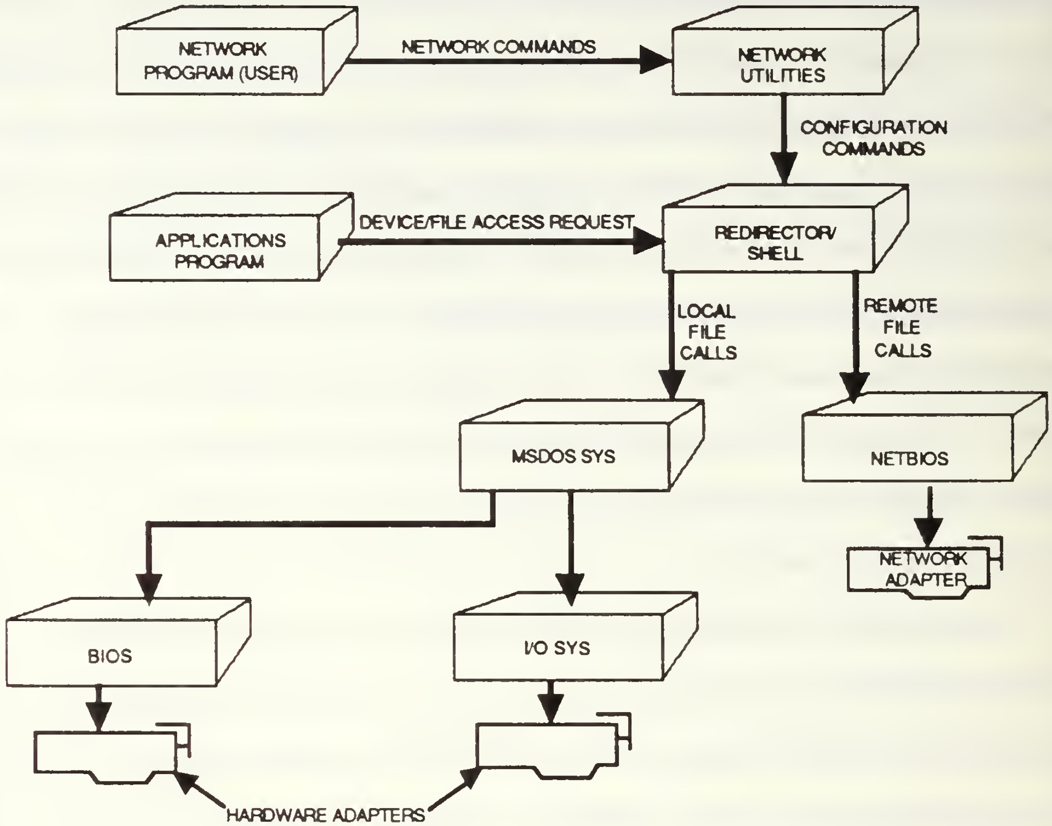
which do not rely upon MS-DOS to manage the network and devices connected to them must still be able to interpret and decode software and hardware initiated interrupts passed by user computers. Software developers design software to either access devices using ROM-BIOS directly or using MS-DOS service calls. If the software is required to process information directly across a LAN it may also support NETBIOS (described in Section III.G). Few software developers would write software which could only execute properly under a non MS-DOS operating system. To do so would reduce the size of the potential customer base.

Figure 6 is a general overview of the relationships between NETBIOS, BIOS, MS-DOS and workstation applications. Commands that use the LAN are either I/O requests or network unique functions. The most common use for a LAN is to share devices (e.g., printers or Winchester style disk drives). When an application (or the user) initiates a file call (e.g., send /receive data or print a file), the redirector acts as an intermediary and intercepts service requests (interrupt function calls). The redirector determines whether the file call is for a local or a remote device and then routes the request to MS-DOS (for a local I/O) or to the NETBIOS for transfer across the net (for a remote I/O). For a local call, MS-DOS will either utilized the BIOS commands or it will call the applicable device driver directly. For remote access, the service call will be processed at the file server.

D. PEER-TO-PEER VS DEDICATED FILE SERVERS

Most LANs provide either Peer-to-Peer resource sharing services or utilize a file server. Most LAN operating systems were designed around a UNIX type operating system and a dedicated computer (or some other micro processor driven device) to support network and file server functions. The term file server implies that one or more computers is dedicated to LAN support and is not used as a workstation. This server manages (controls) devices such as printers and mass storage devices for the network. These UNIX based systems were designed to work in a multi-tasking, multi-user environment and many operate much faster than MS-DOS based systems.

Peer to peer services imply that any user can make an attached peripheral device accessible to other users. This type of peripheral sharing is less costly to implement (no file server is required) but leads to slower response time and can hinder network expansion. If system response time (when using shared peripherals) is significantly degraded, one of the user computers can be configured as a file server with a subsequent increase in performance. For the purpose of this thesis, the most important difference between LANs using peer to peer communications and those using dedicated file servers is the speed with which they respond to network operations. Networks used to support lab tests could be configured for Peer-to-Peer communication or dedicated file servers.



Source: Communications and Networking for the IBM PC & Compatibles, p. 295, Brady Books, 1987.

Figure 6. LAN Software Relationships

E. EXTERNAL PERIPHERALS AND DEVICE DRIVERS

How well a hardware device supports MS-DOS conventions (and networking) is often determined by the device driver. Device drivers are designed to act as an intermediary between the operating system and the hardware device. The device drivers follow a set of rules and specifications issued by Microsoft (for MS-DOS) or other software companies (for non

MS-DOS operating systems). When a command is sent to a controlled device, the device driver receives the order, interprets the instruction, changes the command to one which is suitable for the hardware device and then executes the instruction. Because of this constant control feature, most device drivers will reside within main or expanded memory. MS-DOS release 3.20 expanded the role of device drivers by providing more capability for the device driver in the areas of physical control, networking and device sharing. [Ref. 5].

If a device is to be shared across a LAN, then it must still have some way of receiving primitive control calls to the device driver to support device activity. There are several ways in which this can be accomplished:

- The device request is acted upon at the user computer and MS-DOS primitive groups are passed across the network and are subsequently acted upon by the device driver at the file server (or computer sharing the device).

- An interrupt which is directed to a remote device could be intercepted by the LAN operating system where the interrupt is processed and passed as a series of primitive actions by the network operating system. Upon receipt of these primitives at the file server, the network operating system (resident on the file server or computer sharing the device) communicates with the device driver in a manner similar to that described in section II.D.2. For this method the device driver must reside on the computer which is physically attached to the peripheral device.

- The interrupt which is directed to a remote device is intercepted by the LAN operating system and is passed as an interrupt to the computer which has the peripheral device attached. The interrupt is then passed directly to MS-DOS (in the case of an Int 21 function call), or to the ROM-BIOS (e.g., Int 25, absolute disk read).

F. MEMORY MANAGEMENT

Every feature implemented by a network extracts a charge from the users in the area of memory usage. The amount of overhead (RAM encumbered) associated with various LAN support packages can be up to 130 kilo-bytes of RAM for workstations and as high as 300 kilo-bytes of RAM for file servers. This space is used not only for control requirements but also for the buffering and I/O requirements associated with any LAN. The actual space used by various products is shown in Table 5 [Ref. 7]. Add to this RAM used to support installed device drivers, RAM used as a buffer for file transfers and the RAM used by the MS-DOS operating system and the 640 Kbytes of RAM available on most microcomputers is reduced to between 256 and 512 kbytes. Note that networks which implement Peer-to-Peer resource sharing are the most costly in terms of RAM. Some programs, like IBM's PC LAN program can occupy 350 kbytes for a server and 160 kbytes for a user computer. (actual PC LAN v1.2 figures) Many optical storage devices use complex software to support file location and retrieval. This software often loads a portion of the data base index to RAM or the support device's winchester disk drive. This is done to improve the data access time but it also increases the amount of overhead for the user computer. This additional memory requirement is typically not applicable to WORM devices. The reason for this is related to the way that the different types of optical devices are used. Many WORM drives are used for active archiving of data. This implies that transactions or records

TABLE 5. RAM USAGE FOR VARIOUS LAN

PRODUCT NAME	RAM(server/workstation)
Net/30 Invisible Software Inc	100K/60K Cannot be Unloaded from RAM
Network-OS CBIS Inc	145K/60K Cannot be Unloaded from RAM
LANtastic Artisoft Inc	40K/10K Cannot be Unloaded from RAM
PC/NOS Corvus Systems Inc	194K/66K Cannot be Unloaded from RAM
ELS Netware II Novell Inc	640K/60K **Can** be Unloaded from RAM
LANsmart Localnet Communications Inc.	150K/110K Cannot be Unloaded from RAM
DNA Networks DNA Networks Inc	128K/8K Cannot be Unloaded from RAM
ViaNet Western Digital Corp	106K/96K **Can** be Unloaded from RAM
TOPS/DOS TOPS	180K/79K **Can** be Unloaded from RAM
DataLAN 4 Datapoint Corp	145K/60K Cannot be Unloaded from RAM
POWERlan Performance Technology	145/60K Cannot be Unloaded from RAM
PC LAN 1.1 IBM Corp	257K/192K Cannot be Unloaded from RAM

Source: PC Magazine, Vol 8, No 6, 28 March 1989 from article "Penny-Pinching LANs"

are written to the WORM as they occur (or are collected until the end of some period before being written to the device). Applications which access this data do not require complex search algorithms because the data storage is sequential and not optimized. In contrast CD-ROM data bases are specifically laid out and mastered to maximize search speed and minimize retrieval time. As a result the indexes can take up as much room as the data. Minimum memory requirements for most popular optical

retrieval software is 512 kbytes. Many manufacturers have released expanded memory cards which allow a user to specify expansion memory as an additional disk drive. This solution is realistic for those applications which normally use the server's winchester disk drive. When using MS-DOS extensions (described in section VI.D.3.a), allocation of sufficient RAM space for buffering can make a difference of several orders of magnitude. One parameter which is used when installing the MS-DOS extensions is the amount of space allocated for path tables. A path table provides the location of every directory on a CD-ROM and if the path table is resident in memory then the number of CD-ROM accesses is reduced. Allocating only 8 sectors for an application with a path table size of 10 sectors will cause multiple disc accesses to load the appropriate parts of the path table and a visible slow down in system operation. If a CD-ROM application exhibits a slow response time, buffer assignment is the first thing to examine. If sufficient memory is available to support CD-ROM applications and the path length required by a specific application is unknown then increase the sector allocation. The path size for various applications can be found with the installation information for most commercially produced discs..

G. NETBIOS

NETwork **B**asic **I**nput/**O**utput **S**ervices or NETBIOS is a network counterpart to a PC's BIOS (Section II.C.1) and was developed by IBM to provide a standard for the basic services needed to operate PC based

networks. The specifics of the NETBIOS have been freely distributed by IBM to encourage software developers to standardize their network access requirements. The NETBIOS is network independent and can be used to support Token Ring, Ethernet or other network control mechanisms. It enables programs written for use with the NETBIOS interface to communicate over various types of nets. It manages the lower layers of the mechanics of communication. It notes where data is going, establishes communications with destination computers, breaks data into packets and reassembles the received packets into data. [Ref. 8]

H. NETWORK TOPOLOGY

In theory, the network itself should be invisible to the using application/computer. IBM's NETBIOS introduced earlier and similar interfaces provided by other vendors are designed to transfer information across a LAN without involving LAN users. The topology and physical management of the information packets passed by the NETBIOS are also invisible to the LAN users but have a significant impact upon speed of execution and availability of remote resources. This section addresses two frequently used LAN topologies: Token Ring and Carrier Sense Multiple Access/Collision Detect (CSMA/CD) LAN. One specific type of token ring topology which may have future application for shipboard uses of optical devices is SAFENET.

1. Token Ring

A Token Ring Network appears as though each workstation were connected to only two others; one workstation which receives transmitted

data and one workstation which sends data. In a token-ring, a single token is circulated around the ring when all stations are idle and no data is being transmitted. When a station has data to transmit, it must wait until it can seize the token - an access granting message.

On receiving the token, the station transmits the data. A data frame circulates from node to node around the LAN and when the frame passes the station to which it is addressed, the data is copied to the station and sent to applications software for processing.

The data frame then completes the circuit around the LAN, returning to its sending station. That station removes the data and releases a token to continue the token-passing process. [Ref. 9]

a. SAFENET

One offshoot of the Token Ring handling family of Local Area Networks is the Navy's **S**urvivable, **A**daptable **F**iber-Optic Local Area **Net**work or SAFENET. SAFENET is based on the emerging FDDI standard and the IEEE/ISO 802.5 token passing ring standard and is part of the Navy's Next Generation Computer Resources program. The network can operate at speeds up to 100 megabits/sec and has several features which make it ideal for shipboard support.

Media **a**ccess **u**nits (MAU) are used for connecting workstations into the Token Ring Network. At each of the eight available connectors there is a relay which controls workstation access. When the lobe which goes out to a workstation is idle or disconnected, the relay short circuits that lobe. At the same time the lobe not only excludes the

workstation from the ring, but it connects back onto itself and becomes an independent closed loop. This feature means that SAFENET is capable of casualty recovery. Wiring faults can be isolated and the network can be returned to operation using ring switching and wrapback. This is accomplished by configuring the network with completely redundant separate rings. When a "hard" error is detected in the token-ring, the offending node disconnects, either voluntarily or by the forced actions of its neighbors. Figures 7 and 8 are examples of SAFENET in normal and casualty operation. [Ref. 9]

b. Strengths

- There is no contention for net usage. Two stations cannot transmit data at the same time, so there is no way for frames to collide as in an Ethernet type network.

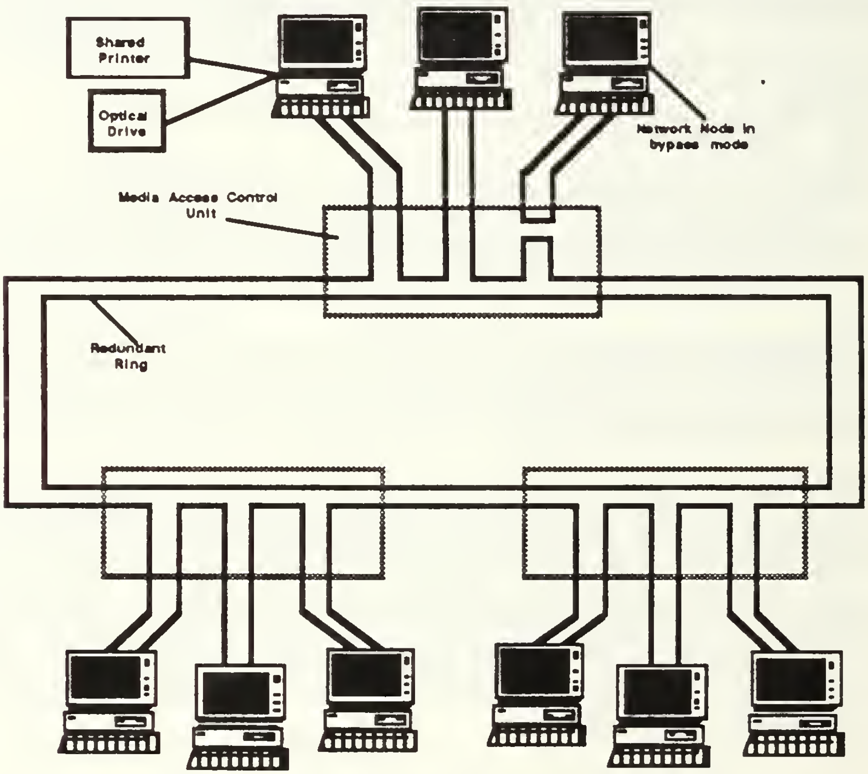
- Token ring networks are controlled by tokens. The use of this simple device simplifies network operation and reduces overhead in large LANs.

- If a priority access scheme is not used, then the maximum period of time between accesses is not predictable (not probabilistic). There is a guaranteed worst-case time to transmit a data frame. With CSMA/CD the time to transmit a message is not predictable (A draw back when accessing optical storage devices). It is conceivable for one user to experience poor response time due to multiple collisions.

- Fast, on IBM PC twisted pair connectors can support a baseband signal up to 4 megabits per second. Use of higher quality twisted pair cable will support baseband signals up to 16 megabits per second. The use of FDDI can support even higher speeds. Note that typical transfer rate for a CD-ROM is 250 Kilo-bits-per-second (limited by rotational speed of the media). [Ref. 10]

c. *Weaknesses*

- Large files will require multiple transmissions
- As number of users increases/period between accesses increases but not nearly as much as with ETHERNET.
- A Token ring has excessive overhead in a sparsely used LAN. NOTE that the use of FIRMWARE to control each computer makes the overhead less important.



Source: IEEE Network Magazine v 1 n.1, p. 28, January 1987

Figure 7. SAFENET Normal Operation

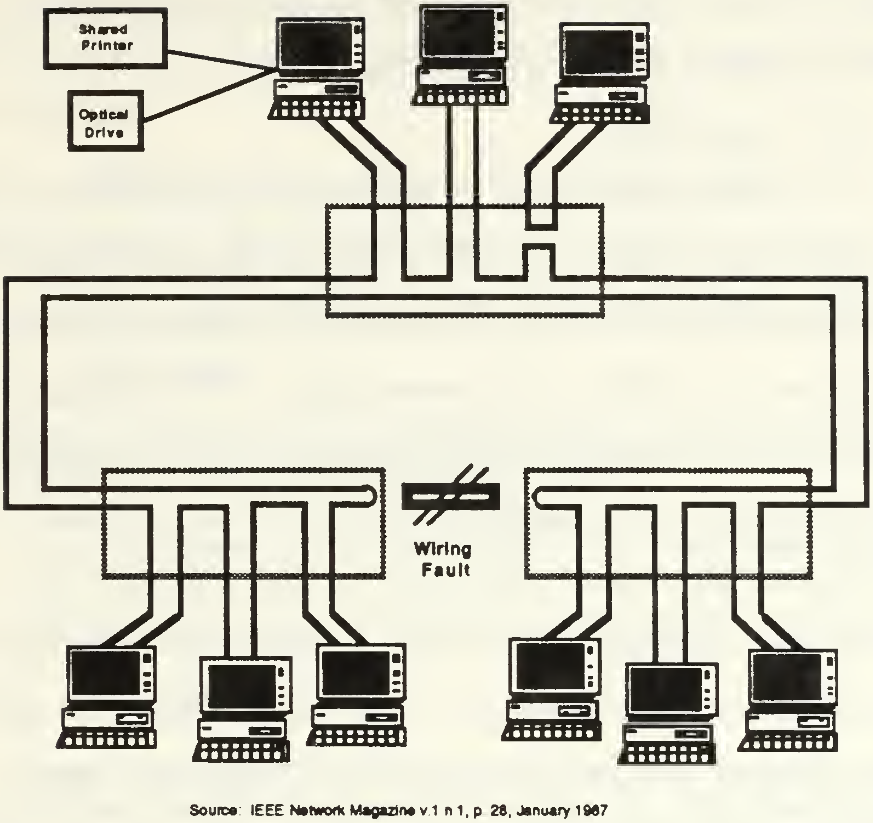


Figure 8. SAFENET Casualty Recovery

2. Ethernet:

Ethernet is the name typically given to contention based **C**arrier **S**ense **M**ultiple **A**ccess with **C**ollision **D**etect (CSMA/CD) networks. CSMA/CD has a recognized IEEE standard (802.3) and is the most frequently used type of network. CSMA/CD utilizes BASEBAND or BROADBAND technology. The BROADBAND version will be described. The applicable total bandwidth is broken down into separate frequency bands (one frequency for transmitting, a different frequency for receiving). This requires the use of a translator which receives information at the

transmission frequency and converts it to the receiving frequency. The translator is located at the Head End of the network.

a. *Operation*

Workstations listen for the presence of a carrier on the network and will send information only when the network is clear. After the network is determined to be clear, the sending workstation prefaces its transmission with the initiation of a carrier signal. Two workstations can simultaneously sense that the network is free and begin transmitting at or about the same time. Because this is a random network access scheme, there is a chance of collision (contention). During the period of transmission the workstation continues to monitor the line for the presence of other carriers and/or data packets. The maximum length of time a workstation will wait is equal to the maximum propagation delay (considered to be double the time required to transmit to the most remote station). The presence of another signal would signify a collision. If no collision occurs then the receiving workstation will send receipt acknowledgement back to the originating workstation. If a collision does occur, the unit which detects the collision will transmit a jamming signal so that others using the network are aware of the problem. The transmitting stations (which experienced the collision) will then wait a random length of time and retransmit. While the workstations which collided are waiting a random period of time to retransmit, other workstations within the network can transmit. The amount of time the workstation waits before retransmitting is called a slot. The slot is the maximum amount of time it

takes for a workstation to start transmitting a message and detecting a collision. Note that the closer workstations are to one another the less chance of a collision

Ethernet an be configured in a variety of topologies (as can a Token Ring Network). Most often Ethernet is thought of as a bus topology. In reality, it can support bus, ring or star topologies. [Ref. 11].

b. Strengths

- Because it doesn't have to wait for a token, each workstation has a chance at the Network when it needs it.
- A user can take and hold the channel for long transmissions
- It requires very low overhead for an infrequently used net.

c. Weaknesses

- A user cannot predict the time delay between transmissions. One user could conceivably utilize all of the Ethernet resources, however, this is unlikely because of the random nature of transmissions.
- Overhead increases as LAN load increases.

I. SUMMARY

To install optical storage devices on a LAN, it is necessary to understand how information is passed across the physical LAN as well as how the network operating system (NOS) functions support I/O using either the NETBIOS or MS-DOS services. Various NOS use different strategies to support LAN utilities but all of them are designed to react invisibly to

applications and to the user. Future sections will address Network operations and how a significant modification to MS-DOS (addition of the MS-DOS extensions) affect LAN operations.

IV. OPTICAL STORAGE DEVICES

A. INTRODUCTION

The first section introduced optical storage devices and some uses within the Department of the Navy. This section addresses each of the major types of optical storage devices and provides a general description of their features. Information pertaining to the physical construction and make up of CD-ROM is also included. WORM and erasable optical storage devices receive a much more general treatment because there is presently no single format standard therefor each manufacturer's physical construction and data format are different.

B. WRITE ONCE READ MANY (WORM)

1. Technology

As the name implies WORM drives can be written to but data cannot be erased or modified once it has been written. As such WORM drives are primarily used as archival devices (often used in conjunction with other mass storage devices). Although WORM drives have been available since 1983, they suffer from a lack of standardization. Very few drives can read from (or write to) a WORM disk from another manufacturer. The technique for writing information to discs is as varied as the manufacturers. Most WORM cartridges are comprised of one or more layers of vacuum-deposited metal film. Writing to the disks is performed by melting holes in the film with the laser, making bubbles in the film or by fusing several

layers. Some WORM discs have pits already pressed into the material, which is then covered with a film to make a bubble. The laser writes to these discs by popping the bubble to expose the pits. The rotation technique for all WORM discs currently on the market is constant *angular* velocity (CAV). CAV drives spin at a constant *angular* velocity and the density of the information storage is determined by its distance from the center of the disc. The most densely recorded material being towards the center. The use of CAV allows for precise head positioning during seek evolutions and is the same way in which magnetic storage devices read and write information. [Ref. 12]

Device drivers for WORM drives accept standard primitive instructions and allow WORM drives to react to interrupt driven commands in the same manner as magnetic storage devices. Applications writing information to (or retrieving information from) WORM drives respond just as they would to any magnetic device. This implies that a WORM drive has a format feature which is equivalent to a file allocation table (FAT, see Section IV.E.1). A FAT maintains information on all active sectors and is constantly updated on read/write devices. On a WORM drive, a new FAT table must be written whenever a change occurs. In actuality, the commands that a WORM device driver will respond to are a subset of the commands which are available for a magnetic drive (e.g., some drives will not support the MS-DOS "SHARE" command which impacts on their usefulness on a LAN , see Section VI.D.1). [Ref. 13]

2. Uses of WORM Drives

The use of WORM (Write Once Read Many) drives can be easily compared to the use of microfiche. Both technologies are designed for storage of massive quantities of information in a small space (see Figures 9 and 10 for space and size comparisons). WORM drives provide storage of 100 megabytes to 3.2 gigabytes of storage per removable cartridge. The largest WORM storage device currently available is marketed by Sony and uses a jukebox which will allow users to access up to 50 cartridges of 3.2 Gigabytes each (or approximately 80 million pages of text).

While information cannot be modified after it has been written, there are occasions when file modification is desirable (e.g., software application upgrades or data base record modification). Most value added resellers (VAR) distributing WORM drives will add utilities to make it appear to a user that a file has been erased or modified. The method of updating files uses pointers to circumvent unnecessary or unusable information. The pointers provide connections between unmodified and new data. With the correct software, however, all information which was written to the WORM is still accessible. This inability to modify the data without destroying the medium is one of a WORM drives most appealing characteristics. It provides an archival method of immense size with access capabilities orders of magnitude better than magnetic tape or microfiche. Because old data is always available (and auditable), many state legislatures and the Internal Revenue Service have declared that WORM discs can be legally used for document storage in the same

manner as microfiche as long as strict auditing procedures are maintained. A similar decision by the US Government could greatly simplify and automate present paper storage of financial records.

A SINGLE CD-ROM CAN HOLD THE SAME INFORMATION HELD BY

- *270,000 PAGES OF TEXT OR,*
- *20,000 PAGES OF IMAGES SCANNED AT 200 X 300 DPI OR,*
- *10,000 PAGES COMPRISED OF 1/2 TEXT AND 1/2 GRAPHICS OR,*
- *1,500 5 1/4" FLOPPY DISKS OR,*
- *1,200 MICROFICHE CARDS OR,*
- *1,104 HOURS(46 DAYS) OF DATA TRANSMISSION AT 1200 BAUD OR,*
- *27 20-MB WINCHESTER DISKS OR,*
- *10 STANDARD 1/2", 9-TRACK TAPES OR,*
- *1 HOUR OF FULL MOTION, FULL SCREEN, FULL COLOR VIDEO*

Source: OPTICAL LASER TECHNOLOGY, SPECIFICALLY CD-ROM, AND ITS APPLICATION TO THE STORAGE AND RETRIEVAL OF INFORMATION, Master's Thesis by David J. Lind, Naval Postgraduate School, Monterey, California, p 24., June 1987

Figure 9. CD-ROM Weight Savings

As was previously mentioned the largest problem with WORM drives is media incompatibility. WORM drive manufacturers have not adopted a storage and access standard as the CD-ROM industry has (High Sierra Group standard and ISO standard 9660). Presently every WORM manufacturer's equipment requires its own cartridge. That means that a data base cannot be duplicated and forwarded to a related activity unless that activity is using the same type of drive. An additional problem is that if a user is less than satisfied with his/her WORM device, he/she is restricted

to procuring additional equipment from the same manufacturer or risk losing all of the information presently being maintained on the WORM. Table 6 provides a summary list of features from various WORM manufacturers.

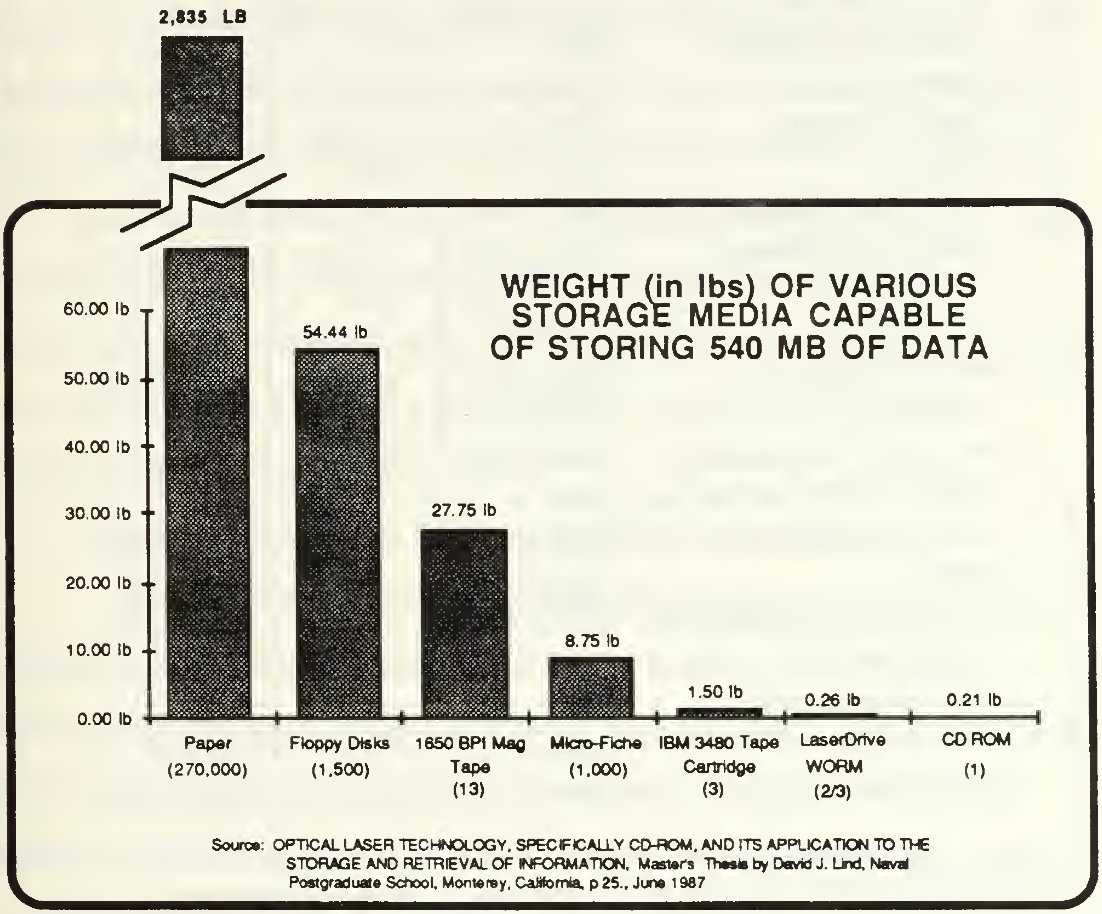


Figure 10. Optical Drive Weight Savings Chart

TABLE 6. FEATURES OF WORM DRIVES

WORM Drives

Vendor	Formatted Capacity Megabytes	Access Time, Millisec	Data Transfer Rate kbit/sec
Advanced Graphics Apps Inc.	800--2,000	108--150	1,200
Cherokee Data Systems	600	135	5,000
FileNet Corp	160,000+	8,000	2,000
Hitachi America Ltd.	600--2,600	93--250	440--1,500
IBM Corp.	200	230	2,500
Information Storage Inc.	244--2,560	90--135	2,500--6,500
Laser Magnetic Storage	654--2,000	75--150	1,250--1,330
LaserData Inc.	400--1,000	150	300
Laserdrive LTD.	405--810	175	272
Maximum Storage Inc.	244--760	28--135	2,500-5,000
Maxtor Corp.	786	133	1,250
Micro Design International Inc.	420--3,202	65	70--300
Mitsubishi Electronics America Inc	600	70--80	1,500
N/Hance Systems Inc.	244--2,560	75--135	600--10,000
Optimem	2,000--4,000	150	625--1,250
Pioneer Communications USA	654--1,500	77--250	650--1,500
Shugart Corp.	400	195	2,200
Storage Dimension Inc.	786	108	2,500
Verbatim Corp.	6,800	9--700	10,000
Wang Laboratories Inc.	2,000	150	256

Source: Govt Computer News, v8,n4, pp. 62-64, February 20, 1989

C. ERASABLE OPTICAL DISK DRIVES

1. Technology

Erasable optical disk drives are just now being seen in marketable quantities (and at realistic prices). Erasable optical drives use a technology that relies on a laser to read and write information and is thus

similar to that used with CD-ROM and WORM drives. A laser is used to heat the surface of an optical disk which then is subjected to a magnetic field which aligns the media to represent 1's and 0's. To erase the disk, it is once again heated by a laser beam and subjected to an alternating magnetic field which effectively erases any data. Because the media must be subjected to both thermal and magnetic energy to allow modification or erasure, it is nearly as durable a medium as that provided by a WORM or CD-ROM. The disk read relies on the Kerr effect, in which the laser beam that reads the data is reflected by polarization changes due to magnetization of the recording layer. The head senses magnetic change as the disk revolves beneath it and registers ones and zeros as the magnetic orientation fluctuates.

2. Use of Erasable Optical Storage Devices

The use of erasable optical storage devices is identical to that of magnetic mass storage devices. The drives respond to the same commands as magnetic drives and there are no reported incompatibilities with PC software products. The reason for this is the use of CAV and standard magnetic drive features such as FAT, sectors and segments. A comparison between magnetic storage devices and CD-ROM appears at the end of this section.

Unlike the WORM market the media is relatively standard. Data input with one vendor's drive can be read from other drives as long as both

were provided by the same original equipment manufacturer[3]. Two standards currently exist for erasable optical devices. One from the International Standards Organization (ISO) and one from the American National Standards Institute (ANSI). As additional manufacturers start to distribute erasable storage devices, it is anticipated that they will conform to these two standards thus preventing the confusion which is apparent in the WORM market. [Ref. 14]. Table 7 provides a summary list of features from various erasable drive distributors.

TABLE 7. FEATURES OF ERASABLE OPTICAL DRIVES

Erasable Optical Drives

Vendor	Formatted Capacity Megabytes	Access Time, Millisec	Data Transfer Rate kbit/sec
Advanced Graphics Apps Inc.	650	61	1,200
Alphatronix Inc.	650	83	7,000
Canon USA Inc.	512	90	6,600
InSite Peripherals	20.8	65	1,600
Maxtor Corp.	650--1,000	35	10,000
Sony Corp. of America	594--650	95	620--680
Verbatim Corp.	60	30	1,500--2,100

Source: Govt Computer News, v8,n4, pp. 62-64, February 20, 1989

[3] As this thesis is being written, only two manufacturers are providing erasable disk drives: Sony and Ricoh. All other vendors are value added resellers (VAR) who receive their erasable drives from one of these manufacturers.

D. COMPACT DISC READ ONLY MEMORY (CD-ROM)[4]

1. Physical Structure of CD-ROM:

CD-ROM discs are 120 mm diameter discs with a 15 mm hole in the center, 1.2 mm thick with data stored on a spiral track .6 microns wide (approximately 16,000 turns per inch) made of a high strength durable polycarbonate plastic. Data is stored in pits and lands (see Figure 11) in frames comprised of twenty four, eight bit symbols (either 24 bytes of computer data or twelve, sixteen bit sound samples), eight control bits and eight, eight bit error correction symbols. There are 7,350 frames in each second of play , 60 seconds in each minute of play and 60 minutes of play per disc. This equates to 635 megabytes of usable data with no error correction or 540 megabytes with error correction. Data from each sector are scrambled during pressing and a cross-interleaved Reed Solomon code (CIRC) is used for error correction. Using CIRC, data are scrambled so that scratches, smudges and other minor disc defects will not damage it. Because each byte of data and its correction code are spread across the disc, the defects act as though it were spread into many small errors surrounded by good data which can be corrected using error correction techniques. The recording format is a spiral groove approximately 3 miles long. Each disc can have from one to ninety-nine tracks with each track comprised of either data or audio (but not both).

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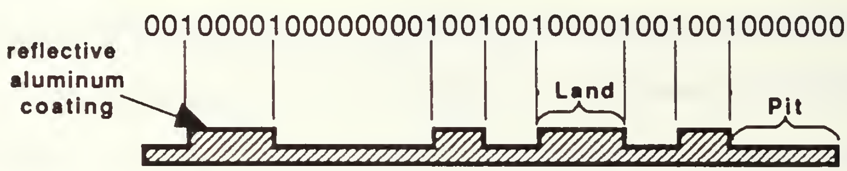
[4] for a more complete description of CD-ROM technology, see the theses written by D. J. Lind and J. S. Johnson.

CD-ROM drives use a constant *linear* velocity (CLV) rotation technique for reading information. This implies that the density of data written to a disc is constant throughout the entire disc. This can be compared to the constant *angular* velocity (CAV) routine used by most magnetic drives and other optical



Pit: microscopic depression in the reflective surface of a CD-ROM

Land: raised and reflective surface between 2 adjacent pits.

Binary 1: the transition from pit to land and land to pit.

Figure 11. Physical Construction of CD-ROM

devices where the density of information is much higher toward the center of the disk than toward the outside. CAV drives rotate the disk at a constant *angular* velocity while CLV drives vary the angular velocity to maintain a constant data density. The advantage of a CAV drive is that individual frames may be directly addressed by track and sector. To move from the current location to the location of the frame, the read head drive motor moves the read head to the correct track and then the disk rotates to the selected sector. When CLV is used, data are arranged sequentially along a

spiral track. This is a very efficient way to store information but complicates random access. The address is recorded not by track and sector but by a minute: second: sector address. Locating a specific address involves moving the head to the general area, adjusting the speed of rotation, reading the disc and making whatever minor adjustments are necessary to find and access the specific sector. This slows down access time considerably and most discs have an average access time from 350 milliseconds to more than 1 second (see Table 8). Actual measured disc speed is from 200 to 500 revolutions per minute (data passes at 1.3 meters per second). This leads to a minimum access time of 110 milliseconds on the innermost tracks to 300 milliseconds on the outermost tracks (assuming instantaneous seek time) which is slow compared to magnetic media with actual average access time from 10 to 80 milliseconds.

TABLE 8. CHARACTERISTICS OF STORAGE DEVICES

MEDIA	Small Winchester Disk	Large Optical ROM	Floppy Disk	Magnetic Tape	Large Winchester Disk	CD-ROM
Media Cost (in US $)	N/A	15-30	1–5	10–20	N/A	10–20
Drive Cost	500–3,000	7,000–100,000	200–1,500	3,000–15,000	1,000–150,000	500–2,500
Capacity (in MB)	5–50	1000–4000	0.36–1.20	30–300	50–4000	540–680
Media Size (in.)	5.25	12.00	5.25	10.50	14.00	4.72
Access Time (sec.)	0.03–0.30	0.03–0.40	0.03–0.05	1–40	0.01-0.08	0.40-1
Density (bits/in.)	15,000	35,000	10,000	6,250	15,000	35,000
Data Rate (KB/sec.)	625	300	31	500	2,500	150

Source: CD-ROM Volume 2, Optical Publishing, p.37, MicroSoft Press, 1987

Although CD-ROM drives share similar characteristics, two features that differ between manufacturers is the ability to support audio as well as data and the size of the drive's memory buffer. Support of audio output has no relevance for a shared device in a LAN but the size of the memory buffer (if properly utilized by the hardware) can significantly increase the rate of data-transfer. The buffer is used as a temporary repository of information being retrieved from the drive and it allows more data to be read from the disk with each I/O operation, reducing the total time required to retrieve the data. [Ref. 15]

E. DIFFERENCES BETWEEN FIXED & OPTICAL DRIVES

A description of data storage on optical discs has little relevance to this thesis when taken alone. At this time there are more similarities than differences in storage format between WORM discs, erasable optical discs and magnetic disks. CD-ROM format is however significantly different and a comparison between magnetic disk format and CD-ROM disc format is necessary to identify potential problems associated with CD-ROM use on LANs.

1. Physical Differences

Figure 12 shows a comparison between fixed magnetic disks and CD-ROM discs. Areas that are different include:

- **File Allocation Table (FAT)**: The FAT is used for disk drives to maintain information about disk segments. Each drive is broken down into sectors (smallest addressable space) and clusters (smallest disk controlled space). The FAT keeps a record of which clusters are in use, bad, free or available for

rewrite. The FAT is updated any time data is written to or erased from a disk. WORMs must use an additional method of controlling clusters as each one can be written only once. When the system tries to erase a file, a file status table is modified indicating that the file is no longer active. CD-ROM discs have no need for a FAT at all. Once a disc has been pressed, the information available on that disc will not change. The FAT would thus serve no purpose. Instead of a FAT, CD-ROM discs use path tables and directories. [Ref. 5]

- **Partitions**: Partitions are used by MS-DOS to divide a fixed disk into separate logical drives. This allows different operating systems to share the same drive. It also provides a method for overcoming the 32 megabyte limit which is imposed by MS-DOS. This size restriction is based upon a sector size of 512 bytes and a 16 bit address register (512 bytes $\times 2^{16}$ = 32 megabytes). One way to overcome this limit is to increase the sector size. Optical storage devices with their mass storage capability make partitioning ineffective and difficult to manage. A single compact disc can have up to 635 Megabytes of addressable space. To make use of an optical storage device, the system could use a sector size of 10 kilobytes or it could use twenty 32 megabyte partitions or a combination of a larger sector size with a number of partitions. To access large data bases with more than 32 megabytes (a common occurrence in Optical Storage), the application would then have to perform searches across partitions. This would complicate the application and slow down operation.

- **Sector size**: The standard sector size for most MS-DOS devices is 512 bytes. The sector sizes for a compact disc per the ISO 9660 standard are Mode 1 (2048 data bytes followed by error correction codes) or Mode 2 (2336 data bytes with no error correction codes). One sector is the smallest amount of data which is transferred to or from the disk drive. The use of a sector size approximately four times the size of the standard MS-DOS sector implies that the minimum buffer which can be used for data transfer is four times the size of the minimum buffer for an MS-DOS device.

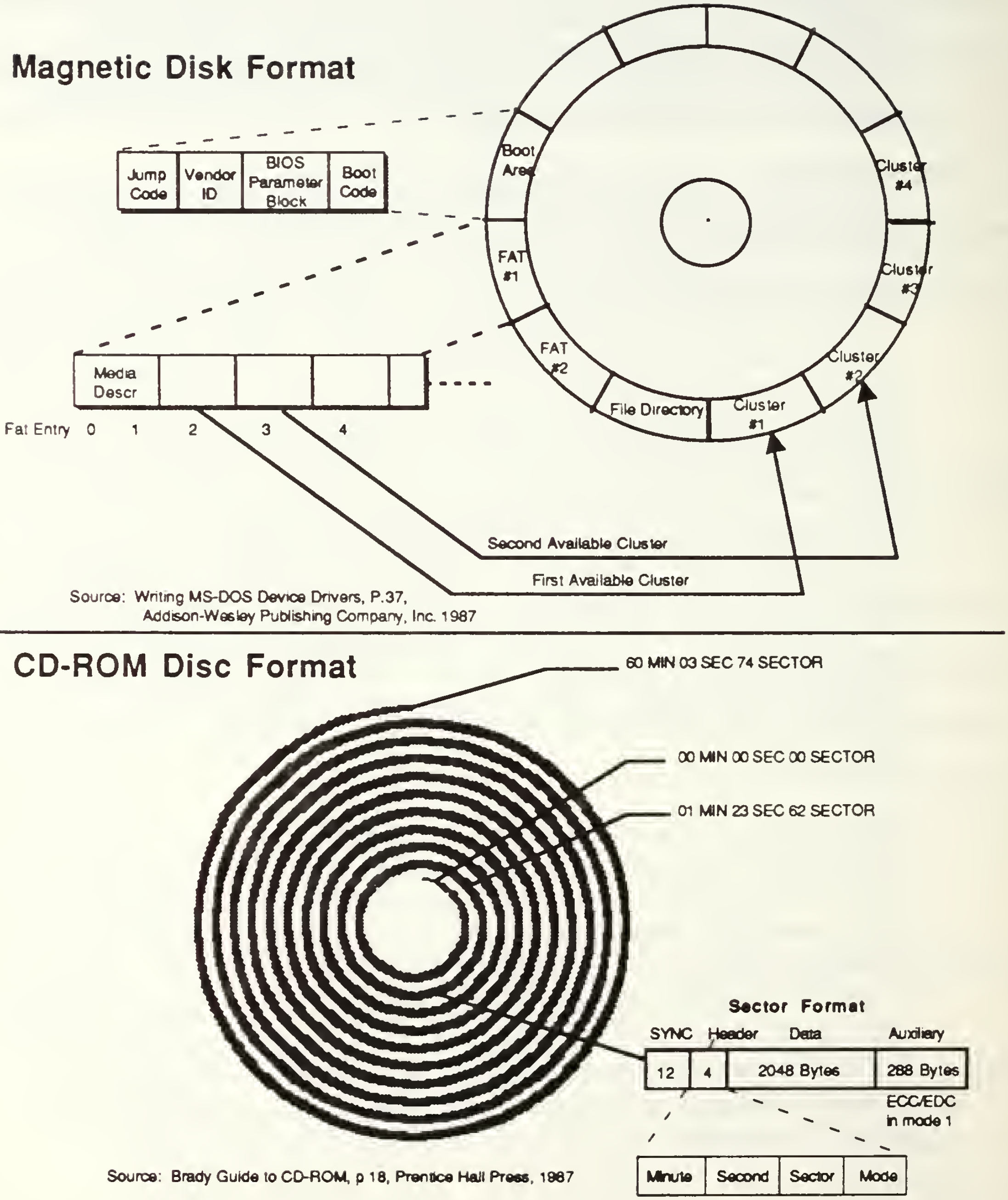


Figure 12. Comparison of CD-ROM and Magnetic Disk Format

- **Clusters**: To speed search and retrieval from mass storage devices, disk drive sectors are grouped into clusters. (for most hard disks a cluster is comprised of 8 sectors). The use of clusters limits the number of possible files for any disk device as well as reducing the space requirements for the FAT (file allocation table).

- **Chain**: A chain is a list of clusters that form the disk space used by a file. The directory used by standard MS-DOS mass storage devices points to the first cluster in the FAT. To read in a file, the device simply reads in data in the sequence specified by the FAT. Chains are not necessary for CD-ROM's (which are pre mastered and thus comprised of contiguous space).

- **CAV vs CLV**: Earlier the difference between CAV and CLV was described as it applied to data seek. CLV (used by CD-ROM) can be an advantage when moving large files. On a CAV device each track has a discrete number of sectors and each track subtends only one complete disk rotation. To read information from more than one track, a CAV device must reposition the read/write head and wait for the correct information to appear. On a CLV device there is only one track and it is in the shape of a spiral from the center of the disc outward. As long as the data being retrieved is contiguous on the disc, the laser beam can follow the track from one sector to the next in much the same manner as a phonograph needle follows the groove on a record album. [Ref. 16]

2. Use of CD-ROM:

Applications which access mass storage devices send standard signals or requests to these devices. These standard requests have to be converted into signals which can be passed to the device for processing. The software (or firmware or hardware) which receives these standard signals and converts them into a usable form takes the form of an operating system extension for CD-ROM. These operating system signals

are then passed to the "device driver" for additional processing and forwarding to the processor which controls the device. Additional information pertaining to device drivers is included in Section II.

The primary use of CD-ROM is to support data distribution (large information service type data bases). Additional uses include distribution of public domain software, archiving transaction data and distribution of integrated software packages. The cost of mastering a disc (and the cost of the workstations used for mastering information for CD-ROM) has fallen by nearly 50% in the last two years and additional CD-ROM titles are being published daily. More than 200 discs have been published covering everything from Ada Language code libraries to Webster's dictionary.

3. Advantages of Optical Storage Devices

The advantages associated with the use of optical storage devices include more than just the massive amounts of information which can be accessed from a single inexpensive device. Other significant advantages include:

- Optical discs can be stored almost anywhere and will maintain their data even if exposed to extremes of temperature and humidity. [Ref. 17]

- Optical discs are not susceptible to disruption or damage from electronic equipment. A WORM or CD-ROM disc cannot be degaussed.

- Additional WORM and erasable disk cartridges can be purchased for $50 - 100 providing unlimited storage space.

- Optical discs can easily be safeguarded when not in use. Cartridge sizes range from the size of a three and one half cartridge (similar in shape and size to that used by three and one

half inch floppy drives) up to the size of a thick phonograph record. (as compared to installed fixed disks which may require safeguarding the entire computer).

- Data maintained on WORM cartridges or Compact Disc is non-volatile. There is no chance of electro magnetic devices, airport X-Ray machines, electro magnetic impulse or clumsy operators inadvertently destroying (or modifying) valuable data. Compact discs cannot be written to at all and WORM drives may appear to modify files but in reality all data written to a WORM drive remains accessible utilizing various utilities provided with the drives. The volatility of erasable optical drives is different. Operators or disgruntled employees can modify erasable optical media and it appears to have many of the inherent vulnerabilities associated with electro magnetic drives, with the exception that it is not vulnerable to electro magnetic or other radiation caused disruption. The material utilized for erasable drives can be magnetically modified only after the media has been raised above a specific temperature. The chances of the media being accidentally subjected to this modification temperature and a high intensity magnetic field at the same time is remote.

- Disc crashes are not possible. Optical storage devices use low power diode laser beams and optical pickups . There is no physical read/write head which is in close proximity to the rotating media.

- There is no physical wear because the optical pickup and low yield laser never touch the disk. Magnetic tape travels directly over a read/write head. Read/write heads for floppy disk drives are always in constant contact with the disk. Tapes and floppy disks are subject to wear with repeated use. Winchester style fixed media drives do not use a read/write head which directly contacts the disk being read. However, repeated and consistent magnetizing can wear out the media. This media can also be subject to head crashes leading to permanent damage to the storage media.

- Optical storage media is extremely durable. The data is written to a metallic surface which is protected from damage by an external layer of plastic. This plastic is the same type used in protective

helmets. Data error detection /correction and multi-beam optical synchronization features on most optical drives allow one to continue using a disc even after it has been scratched (a scratch is a surface condition which doesn't directly affect the protected data). A scratch on other types of storage media will normally render that media unusable.

- The shelf life of optical storage media is believed to be in excess of 30 years. Other data storage media including magnetic tape, removable media magnetic storage devices and streaming tape have shelf lives of ten years or less.

4. Disadvantages of Optical Storage Devices

Problems associated with use of optical storage devices include:

- Optical storage devices have slow access times. Erasable drives have access rates of about 60 milliseconds as compared with access rates from 11 to 30 ms for Winchester (fixed) disk drives. Under real world conditions "Shor" estimates that an erasable drive takes about two minutes per Megabyte to write and one minute per megabyte to read. [Ref. 14]. Other optical storage devices are even slower. Access times for CD-ROM discs currently on the market are contained in Table 9.

- The data layout on CD-ROM is not efficient for random access. The layout was driven by the audio recording industry and is best suited for sequential access. To locate a spot on the CD-ROM it is necessary to go to the approximate location, modify the speed to maintain CLV, read the disc to find the actual location and adjust the speed of the disc and placement of the laser beam to account for the correct location. [Ref. 16]

TABLE 9. CD-ROM ACCESS TIMES

Manufacturer	Access Time (ms) Avg	Max	RAM Cache Size
Amdek	700	1000	8 K
Apple	500	600	64 K
Chinon	800	1000	-
Denon	400	1000	32 K
Hitachi	500	1000	8 K
JVC	300	800	24 K
LMSI	400-500	1000	2 K - 64 K
NEC	500	1000	64 K
Sanyo	300	800	32 K
Sony	500	800	8 K
Toshiba	350	650	64 K

Source: CD-ROM EndUser v.1, n.1, pp.14-15, March 1989

V. STORAGE, SEARCH AND RETRIEVAL TECHNIQUES

A. TRADITIONAL DATA SOURCES

1. Online Data Services

The mass storage capacity and huge data bases available for optical storage devices are characteristics which are shared with mainframe data bases and electronic information services. These services allow users to link with information services equipment via modem or direct data link. Although these services are valuable, access to these services is limited by availability and have significant cost overheads for data retrieval. When using these services it is necessary to pay for connection (or subscription) charges, computer access time, communications equipment maintenance, line charges, etc. If data requirements are sporadic and information data base access is infrequent then perhaps these charges are acceptable. If frequent access from large data bases or information services is necessary then optical storage could be a cost effective alternative.

2. Microfiche data storage:

Another frequently used source of information is provided by microfiche. Microfiche data storage is inexpensive and will often provide data as comprehensive as that provided with optical disc distributed data bases and online data services. The disadvantages associated with the use of this storage media are:

- Microfiche use indexes and numbering techniques to help a user access the correct information. These search/retrieval techniques are clumsy and quite time consuming when compared to electronic search and retrieval techniques used for optical storage.

- Microfiche are very bulky when compared to optical storage media. As Figure 9 points out 1,000 microfiche are required to equal the amount of information stored on a small (5 1/4 inch) optical disc.

- Complex searches (a search on more than one key word or theme) using microfiche is very time consuming and might not be possible. Microfiche are typically indexed on a few key data fields. If the specific information being retrieved is not in a key data field then a manual search of individual micro fiche could be necessary.

B. OPTICAL DATA SOURCES

The features of online services and microfiche that ideally suit them for information services is that they provide mass storage at a low cost (shared cost in the case of online services). Duplication of information services on Winchester disk drives is very expensive (600 megabytes of Winchester storage could cost $10,000 to $20,000 for the hardware alone). Using Winchester disk drives, if additional data storage is required, it is necessary to purchase additional disk drives.

The introduction of optical storage and the rapid growth of high fidelity audio compact discs led to the distribution of data in optical format. WORM drives (and more recently) erasable disk drives share many of the features of magnetic discs (e.g., constant *angular* velocity, file allocation table) and support information services in much the same way that magnetic devices

do. In contrast, CD-ROM was a spinoff of the audio CD market and most CD-ROM drives on the market will support both data and audio retrieval. In an effort to promote rapid growth of CD-ROM, a number of developers in the optical storage field (Apple Computer, Digital Equipment Corporation, Hitachi, Microware Systems, Microsoft, Phillips, Reference Technology, Sony, 3M, TMS, Video-tools, Xebec and Yelick) met at Lake Tahoe California to develop a CD-ROM standard.

1. High Sierra

One of the major differences between CD-ROM and any other mass storage device was the joint formulation of a data storage format. A standard for storage and retrieval was expected to provide impetus for optical storage development (An example of this was the agreement between CD audio developers to follow a specific standard for encoding music. Any CD audio disc can be played in any CD audio player regardless of manufacturer. This feature coupled with the high quality of CD audio reproduction catapulted CD audio to its present position as the dominant audio storage medium.) The group (named the High Sierra Group or HSG because of its first meeting place) had a number of objectives. [Ref. 18]

- Define block and sector structure as seen by a host computer
- Determine placement and contents of volume labels and develop a directory structure for naming and defining files
- Optimize CD-ROM performance by minimizing the number of seeks necessary to locate data.
- Allow for extension to WORM and erasable optical technologies. The adaption of this standard by the WORM community has not

occurred and WORM drives still use a format which is unique to specific manufacturers. This lack of standard makes it difficult to evaluate the use of WORM drives in LANs (see Section VI.D.1).

- Provide compatibility with CD-I (compact disk interactive)
- Support different character sets for a worldwide standard
- Provide for easy implementation with most popular operating systems

The developed standard coupled with the use of constant *linear* velocity, the ability to process audio data and the 32 megabyte file size restriction of MS-DOS are what necessitate the use of MS-DOS CD-ROM extensions. To better understand the problems associated with CD-ROM on LAN, the features of the High Sierra standard (which subsequently became part of ISO standard 9660 in 1987) include the following:

a. Sector Size

The hardware characteristics of CD-ROM discs was introduced in a previous section. The information dealt with the most commonly used sector size and format. The High Sierra Group specifies the logical sector length to be 2^{n+11} (where 'n' is any positive integer, thus any multiple of 2048 bytes can be used). The reason the sector size is not fixed is to decouple the standard from a physical structure. This allows manufacturers to utilize a sector size which best suits application or hardware requirements. Additionally, the High Sierra specification provides for a smaller unit size called a Block. The standard block length is 2^{n+9} (minimum size 512 bytes) but must be less than or equal to the sector

size. A sector is the smallest unit of information which is directly accessed and a block is the smallest piece of data which the optical storage device recognizes and determines the granulation of the CD-ROM. Each logical block is assigned a logical block number (or LBN). [Ref. 18]

b. Volume Space

The volume space begins at disc address (0,2,0) which is read in minutes, seconds and sectors (The earliest use of CD ROM was in audio applications. The designation of location by minutes, seconds and sectors is loosely tied to that early use. A disc can hold 60 "minutes" of data. Each minute is divided into 60 "seconds". A "second" of data is divided into 75 sectors. Therefore the location (0, 2, 0) refers to minute zero, second two, sector zero. [Ref. 12].) The information which is maintained in (0,2,0) to (0,2,15) is used for system specific interface information. The area assigned for data begins at position (0,2,16). The beginning of the data area includes a volume identification, path table location and the attributes of the CD-ROM files. Instead of requiring contiguous files, the standard uses "file extents". These are parts of a file which are logically connected together using file pointers. Fragmented files seldom occur in a CD-ROM, thus this feature is generally used for performance tuning (if at all). If the standard is ever extended to other optical storage devices then this feature will be important. [Ref. 18]

c. Directory Structure

How long it takes to search a database is dependent upon the directory scheme being used. When a database is accessed from an

external device, the time taken to find a piece of data is determined by the amount of time it requires to locate, read and search the file directory, plus the amount of time required to locate and read the specific data record (or records). The High Sierra proposal allows for a root directory with sub directories up to eight levels deep (up to 256 directories). These directories are recorded as files on the disc and are accessed via a path table. The path table contains the location of all directories and sub directories. One of the requirements of the HSG standard is that no directory file information will be split among sectors. If the disc is divided into several large directories with many files, then much time could be spent searching through multiple sectors to find the correct file. If, however, the directory size is held to forty entries or less (the maximum number of entries in a one sector directory) then all that is required is to search the path table (resident in memory) read in one sector (one directory) and the application will have the required file location. When multiple volume CD-ROMs are used, the retrieval software must use the volume set size field and use the path table that is contained in the volume with the largest number in this field. Directories and path tables are located in a minimum of two locations but can be in up to eight different locations. The seek and latency time for the data search can be minimized by placing copies of the directories in several locations.

Path tables can be contrasted with the tree structured directories used for most mass storage devices. In a tree structure, if a file is located n levels below the root level then at least n seeks would be

necessary to locate that file due to the fact that each directory contains the locations of its sub-directories. [Refs. 18 and 19]

d. XAR

All files can have extended attribute records (XAR). XARs hold additional information which can be application or file structure dependent. Each extent can have an XAR associated with it but only the final extent's XAR is used. One key entry is the record structure. All records are either fixed length or variable length. Fixed length records are 1 byte to 32,767 bytes and are usable only with structured data. If the data are unstructured then an attempt to use fixed length records will require the user to assign the size of the largest record as the fixed size. Variable length records can be 0 to 32,767 bytes in size and take up only the space required by the data plus a record control word of 16 bits which is used to record the record length. [Ref. 18]

VI. OPTICAL STORAGE ON LANS

A. INTRODUCTION

In the first five sections, personal computers, local area networks and optical storage devices have been selectively reviewed. The subjects discussed are those pertinent for connecting the three technologies. The PCs are the system controllers and provide the interface between the user (or the application), optical storage devices and LANs. This section describes the use of optical storage devices on LANs. It will not treat the management of optical devices, nor will it specifically address LAN optimization. Rather the section describes connectivity issues. The use of CD-ROM on LANs receives the majority of the attention.

B. LAN USAGE

Most large LANs utilize a file server . For the purpose of this thesis the term file server refers to the network control center where network management functions are coordinated and controlled. These functions include control associated with file servers, terminal servers, and print servers. A file server is a dedicated microcomputer used to control devices which are made available to the network. A typical file server will provide control and buffer space for shared print devices, manage LAN message traffic and act to coordinate information exchange between workstations and network shared mass storage devices (fixed disk). These mass storage devices respond to operating system commands (primitive

groups) via the server computer. If optical storage devices supported an identical series of primitive groups then the task of connecting an optical storage device to a LAN would (theoretically) be no more complex than connecting any other mass storage device. The compatibility between DOS (any operating system) and the optical device driver will determine how difficult (or easy) it is to connect to LAN. Each type of optical storage provides its own set of challenges and each will be addressed separately.

C. OPTICAL STORAGE LAN ISSUES

Section II (PCs) presented MS-DOS and its role in controlling peripheral devices. MS-DOS also plays a major role in making peripheral devices available to a LAN. MS-DOS 3.1 (and later) includes utilities which are necessary to support shared files on a LAN. The utilities include file access and file sharing attributes, locks and semaphores. One issue is whether an optical disk device driver's interrupt handling includes these utilities. The question of which network topology is correct for providing adequate support for optical storage is a matter of user preference. If the network operating system is properly implemented then this topology is invisible to the user. It was quickly discovered that although this is true in theory, optical storage presents a problem to a network manager. The data access time (60 to 1000 milliseconds depending upon optical device) and the data transfer speed (approximately 150 kilobits per second) can cause significant slow-downs when multiple users are accessing one of these devices. Using a device this slow makes different demands on different network managers. Potential complications include:

- I/O is slowed down by the physical speed of the optical storage device (150 kilobits per second for CD-ROM vs 10 megabits per second for Ethernet, 4 or 16 megabits per second for Token Ring and 100 megabits per second for **F**ibre **D**istributed **D**ata **I**nterface (FDDI)).

- A significant portion of a PC's RAM is utilized to support network operations. RAM requirements include buffers, terminate and stay resident portions of MS-DOS, device drivers and the LAN operating system. An even larger section of RAM is used when device drivers and buffers are added to support an optical storage device.

D. DEVELOPMENT OF DEVICE DRIVERS:

Device drivers must be used to allow reading (or writing) to an optical storage device. The minimum set of functions required for device drivers is dictated by the operating system and the type of device being supported (e.g., CD-ROM device drivers do not have to provide a write capability but must be able to handle user or application initiated attempts to write to the device). Microsoft estimates that development of device drivers to support optical storage devices typically take 1-3 man months. Although the writing of new device drivers probably will not be necessary, third party vendors can write hardware dependent device drivers or provide hardware specific consultation [Ref. 20].

The device driver must be compatible with both the optical storage device and the operating system. In the case of a LAN there are several different ways in which drivers and operating systems affect each other:

- MS-NET based networks are designed to operate with standard MS-DOS device drivers. When a hardware or software interrupt is directed to an optical storage device, all interrupts are

processed as described in Section II. Note that CD-ROM access requires the use of an extension to MS-DOS (see Section VI.D.3.a for a more complete description of the MS-DOS CD-ROM extensions).

- Many LANs which are not MS-NET based, support NETBIOS and provide their own operating system. This operating system resides between the user and the MS-DOS. When a hardware or software interrupt is initiated for a shared device, the LAN operating system intercepts the call and effectively replaces the MS-DOS. These operating systems may (or may not) support MS-DOS device drivers (e.g., Novell products require a device driver written to Novell specifications). The MS-DOS designed device driver will not function properly and must be replaced. The availability of a suitable device driver is critical for correct operation. Note that when using CD-ROM there are additional problems which are addressed in a later section.

- Several LAN (e.g., Lantastic by Artisoft) determine whether an interrupt is intended for a local or remote device. If the device is local, Lantastic passes the interrupt to MS-DOS where it is processed as described in Section II. If the device is a shared remote device then the interrupt is passed across the LAN allowing the file server's MS-DOS to handle the request. All MS-DOS device drivers are recognized by these products. To use CD-ROM, the MS-DOS CD-ROM extension must reside on the file server's computer.

1. WORM Drives

The use of WORM drives in LANs is dependent upon availability of an appropriate device driver. Because of the similarities between magnetic media and WORM media, most MS-DOS disk drive access commands are supported. One problem which occurred was directly related to the write once restrictions which give the WORM its name. Some LAN operating systems provide special security features which can lead to reduced WORM usefulness. An example of this is Novell Netware which

writes all files twice, once as a backup in case of a media error. For Novell Netware WORM users this means that space will be wasted on the WORM drive for every write command executed across the network (ie., a duplicate of the file will be written to the WORM drive and after verification it will be erased). Because of the permanent nature of any WORM write command, one vendor will not provide a device driver capable of supporting connection of their WORM drive on a Novell Netware LAN. This particular drive does support connection to Novell LAN using OptiLan. OptiLan is a software solution distributed by Optisys which "maps" the WORM drive on to the LAN and allows the user to access it like any other shared device.

Another connection problem is related to the completeness of the device driver used. If the device driver does not support the MS-DOS file sharing and attribute utilities then its usefulness on a LAN is significantly reduced. The VAR documentation should include which MS-DOS and NOS commands are supported. Note that device drivers for MS-DOS based networks and other LANs (e.g., Novell Netware) may be different. The fact that the MS-DOS file share utilities are not supported does not necessarily imply that device sharing is not supported for a different LAN (and different device driver). [Ref. 13]

2. Erasable Optical Disc Drives

Every command which can be sent to a fixed storage device has an equivalent in the device driver for the erasable drive. Theoretically this makes connection to a LAN no more difficult than connecting the drive to a

file server and sharing the device. No erasable drive was available for testing but articles in Mac World, Government Computer News and LAN Times all attest to successful use of erasable drives on LAN. LAN operating systems which do not recognize MS-DOS device drivers (such as Novell Netware) require device drivers written to their standards. If the reader is contemplating the use of an erasable optical disk on one of these networks then it is necessary to verify with the VAR that an adequate driver exists for the appropriate LAN operating system. The probability of finding an adequate device driver is dependent upon the size of the potential customer base.

3. CD-ROM Drives

CD-ROM presents the largest problem to sharing the device over a LAN. CD-ROM devices and device drivers must respond to non standard interrupt and function calls. Because of this, a user cannot directly access a CD-ROM without additional support. This additional support is provided by MS-DOS CD-ROM extensions.

a. MS-DOS Extensions

Microsoft has been one of the software leaders in the field of optical storage. Recognizing the unique requirements of optical storage devices, Microsoft introduced MS-DOS extensions to make these devices easily accessible to PC and PC compatible computers. Initial releases of MS-DOS extensions were designed exclusively to support optical storage devices under MS-DOS as stand alone devices (ie., not shared over a LAN). Release 2.10 was introduced to solve many of the problems

associated with supporting optical storage devices on local area networks. This release supports both the High Sierra Group conventions and the ISO 9660 standard for CD-ROM (level one data only, see Section V.B.1). When properly implemented, MSDOSEXT 2.10 makes installed CD-ROM discs appear like a magnetic storage device to the user (and to application software). This release provides support for MS-DOS versions 3.1 through 4.0 and will reportedly work with any network which is an MS-NET type of network (note that MS-DOS 3.1 was the first version of DOS which provided support for the Microsoft network interface. MS-DOS 3.1 provided a method for the device drivers to receive commands via the network). Features of MS-DOS extensions include:

- An installable file system driver implemented as a terminate and stay resident module which can be started using the autoexec.bat file. Terminate and stay resident module indicates that upon installation, the extensions will load into system memory and will remain in memory to handle specific interrupts and system calls (in a manner similar to MS-DOS and memory resident device drivers)

- An entire CD-ROM (potentially 635 megabyte) will appear as one volume addressable with a single drive letter (overcoming the 32 megabyte restriction inherent with MS-DOS)

- They will allow applications to access files on the CD-ROM just as they would on any magnetic style disk drive.

- Software developers do not have to use a special set of commands to access CD-ROM. Standard commands for magnetic storage devices can be used with the exception that the user cannot create temporary files or write to the CD-ROM.

CD-ROM extensions also have limitations. Release 2.10 will support only level one data. Level one and two data is defined as:

> "Level One -- The lowest level of interchange. This level allows only one file section, and restricts file names and directory identifiers to eight characters, and file name extensions to three characters." [Ref. 22]

> "Level Two -- This was planned as the level that would provide the most commonly needed features, and also as the CD-I compatible level. The only restriction is that each file shall only consist of one file section" [Ref. 22],

If the application uses level two data then extra file name and directory identifier data will be ignored. The extensions also use more than 32 kilobytes of RAM. This becomes especially significant when the CD-ROM is used in a LAN. The memory allocated to MS-DOS, LAN, MS-DOS extensions, additional device drivers and memory buffers could restrict the type of retrieval software that can be run. A number of the LAN applications and the MS-DOS extensions (including the memory buffers required to support CD-ROM) can be moved to extended RAM (if available) but even after recovering RAM for resident programs which can be located in extended memory, the user may not have enough free RAM to support CD-ROM retrieval software. [Refs. 15 and 20]

These extensions are licensed to CD-ROM manufacturers and vendors for distribution with their hardware devices. If the user is using an optical storage device with an MS-DOS operating system the extensions may be necessary. The extensions are not distributed by CD-

Disc publishers. They can be purchased from MicroSoft and are generally distributed by the CD-ROM drive manufacturers and VARs.

b. Installation of MS-DOS extensions

When using CD-ROM in a local area network, the LAN manager will have to perform the MS-DOS extension installation **after** installation of the network software. If this is not done then there is contention between the network software and the extensions, resulting in network software failure. MS-DOS extensions recognize other resident software and places itself in a free section of memory thus avoiding contention problems. If the file server is also using a software shell, then the manager must initiate the MS-DOS extensions **before** the start of the shell. Failure to start MS-DOS extensions first will make the extensions unavailable to the system. Execution of shell commands is normally done last. If the shell is started first then either the MS-DOS extensions have to be installed within the shell or installation will not occur until the shell is closed.

Problems associated with MS-DOS extensions:

- Only features of the Level One data structure are supported.
- Multi volume disk sets are not presently supported by MS-DOS extensions.
- Use of MS-DOS extensions is only beneficial if the system is operating under MS-DOS. Unfortunately each LAN implementation takes a different approach to server support. For this reason the approach that the LAN manager takes to instal CD-ROM in a local area network is going to be dependent upon the network software being used. Other products which offer

support similar to MS-DOS extensions include CD NET by MERIDIAN DATA Systems and OPTINET released by ONLINE.

Approaches to be taken with different products:

- **MS-DOS networks**: LANTASTIC and other networks that rely upon interrupt 21 services (and make no assumptions about the type of media being used) should work using MS-DOS extensions. Network solutions provided by Ungermann-Bass or 3Com do not use standard INT 21 calls. These products make assumptions about installed devices and do not use standard calls. Use of earlier (prior to 2.10) versions of MS-DOS extensions appear to allow sharing of the CD-ROM but server requests will not execute properly and will lead to inconsistent drive response. The user can access the device but attempts to read the device send standard magnetic disk primitives to the device driver. The system reads an area of the disc where it expects the FAT and directories to reside. Because of the differences with the physical structure of the CD-ROM, the information returned bears little resemblance to a disk directory and it appears that no files exist on the disc. The "/S" option under MS-DOS extensions 2.10 will fix these problems and allow these LANs to work properly.

- **Novell and PC NET networks**: ONLINE and MERIDIAN have adapted MSCDEX and specific device drivers to provide LAN CD-ROM support. Each workstation makes use of MSCDEX and a pseudo device driver. NETBIOS is then used to transmit the commands to the file server. The file server accesses the CD-ROM device driver and uses the drive normally. The information accessed is then returned to the pseudo device driver via NETBIOS. ONLINE and MERIDIAN provide similar services but the solution provided by ONLINE does not require that the CD-ROM be present on a dedicated file server. Any user can access any other user's CD-ROM drive (if the owner authorizes the sharing). The price for this feature is significantly slower operation (see Section III.D above).

Research was conducted to test the MS-DOS extensions with the IBM PC LAN program in a Token Ring Network. Results of testing appear in Section VII.F.3.[Ref. 20].

c. LAN Product Support

A number of products have been released within the past year to support CD-ROM LAN installation. All of these products use one of the three strategies discussed in Section VI and no single product will support all LAN installations.

Meridian Data, Inc.'s CD Net provides a combination hardware and software solution for CD-ROM installation on LAN. It uses a separate server which is dedicated to the shared CD-ROMs. The server software acts as a shell to the LAN software and is responsible for receiving standard file access requests and passing them to the MS-DOS extensions for processing. The server/device driver combination handles CD-ROM I/O and passes the information to the software shell which then sends the information across the LAN in the same manner as any other call to a shared mass storage device. CD Net currently supports only Novell network software but future releases are planned to support other LANs. The product supports up to six users.

On Line Products Corporation introduced OPTINET, a software solution for CD-ROM installation and is somewhat less expensive than CD Net. OPTINET acts as a shell on both the workstation and the server (and must be resident on both). After set up it intercepts access interrupts for remote CD-ROM and passes the interrupts across the LAN using the NETBIOS. The interrupt is then passed to the MS-DOS extensions and processed in the same way as any other call to a shared mass storage device. It is advertised that OPTINET can support up to 100

users simultaneously, but as with CD Net, response time will suffer significantly with more than five or six users.

E. SUMMARY

Network operation and Optical Storage access are closely related to the operating system. Device drivers which have not been specifically designed to support networking solutions will not fully support operations in a LAN. An operating system which will not allow the sharing of hardware devices will be ineffective for LAN management. Each of these requirements, while necessary, penalize the user. Buffers, network software, device drivers and the operating system all take a portion of the RAM required to support modern applications and data retrieval software. The RAM restriction which is a characteristic of the IBM PC family of microcomputers imposes a significant limitation to the effective use of optical storage devices on LANs. The user will have to make compromises between LAN features, utility software and peripheral devices. Expanded storage provides a partial solution but is little more than a crude work around.

VII. LABORATORY EXPERIMENT

A. INTRODUCTION

Lab work was conducted to determine the feasibility of using optical storage devices as shared resources in local area networks. The lab setup used was limited to available resources and tests were run on a minimal configuration LAN using a physical star topology (one file server and two workstations connected to a media access unit) under IBM Token Ring. Token Ring was selected for two reasons: (1) the school has several IBM Token Ring networks and optical storage devices are being considered for future LAN expansion; and (2) The Token-Ring has the fastest LAN growth rate and will probably exceed ETHERNET in number of installations in the future. Although the LAN was comprised of only three nodes, the fact that all data being passed is broken into packets which are transmitted sequentially, with other nodes receiving the token between packets, means that the LAN works similarly with three or fifteen nodes. This can be contrasted with an Ethernet (CSMA/CD) LAN. Using Ethernet, the larger the number of nodes, the greater the chance of collision and the higher the administrative overhead associated with the LAN. With the few nodes utilized in the lab, it would have been difficult to force contention on an Ethernet network.

B. LAB SETUP

A minimum configuration three node LAN was set up in room 158 Ingersoll Hall at Naval Postgraduate School. The hardware utilized and the Token Ring set up are displayed in Figure 13. The lab set up was designed to test the latest optical technology on the oldest microcomputers routinely used within the Department of the Navy (DON). If tests were successful on the PCs then successful use on an AT compatible computer could almost be assured.

The Token Ring network utilized one MAU (with the ability to support up to 8 nodes). The physical connections (all nodes connected to the MAU) appeared to be in a star topology but the configuration was a logical ring (i.e., the token followed a circular pattern from one workstation through the server, to the other workstation etc.).

The WORM drive attached to a SCSI interface card. The SCSI card has the ability to support up to seven SCSI connectable peripherals and was factory set to a bus address of 300 hex. Because of the large size of the WORM storage (405 megabytes per side) the manufacturer formatted WORM cartridge used a sector size set to 6,144 bytes. Combined with the 16 bits used for sector addresses this allowed for an addressable WORM volume to 402 megabytes (2^{16} * 6144 = 402 megabytes). This large sector size meant that writing files to the WORM would use at least 6,144 bytes regardless of the file size. Frequent updates of a moderate size database could quickly use up the large volume of available space. For this reason, the WORM was used exclusively as an archival device (ie. information was

read from the disk but aside from verifying that writing was possible across the LAN, no information was routinely written to the drive). The device driver used for the WORM was identified as *LDRIVER.SYS* and occupied 6,944 bytes of memory on the file server.

The CD-ROM had its own parallel control card which was set to the same bus address as the WORM drive (300 hex). The bus address could be reset using dip switches and was set to 340 hex to eliminate interference between the WORM and the CD-ROM (see Figure 13). The CD-ROM could support in excess of 540 megabytes of information and required MS-DOS CD-ROM extensions (or some other software which performed a similar function) to overcome the 32 megabyte restriction caused by MS-DOS with 512 byte sectors. The CD-ROM device driver was named S500SI.EXE and occupied 9,552 bytes of memory on the file server.

C. INSTALLATION PROCEDURE

The physical connection of the peripheral devices was straight forward with the exception of the modification to the bus address for the CD-ROM and the fact that the first peripheral slot (closest to the file IBM PC/XT's power supply) would not support the CD-ROM device controller and did not provide enough room for the installation of the SCSI card.

Software installation of the WORM and CD-ROM drive was completed per the manufacturers instructions. The *config.sys* and *autoexec.bat* files which support installation of these devices are included in Figures 14 and 15. Note that the bus address (in decimal) was included as a parameter when the CD-ROM device driver was installed. This parameter was used

to ensure that CD-ROM controller instructions were forwarded to the address supported by the dip switch settings on the controller. MS-DOS CD-ROM extensions were necessary to support operation of the CD-ROM. The installation commands (config.sys and batch commands) for the MS-DOS CD-ROM extensions are shown in Figure 16.

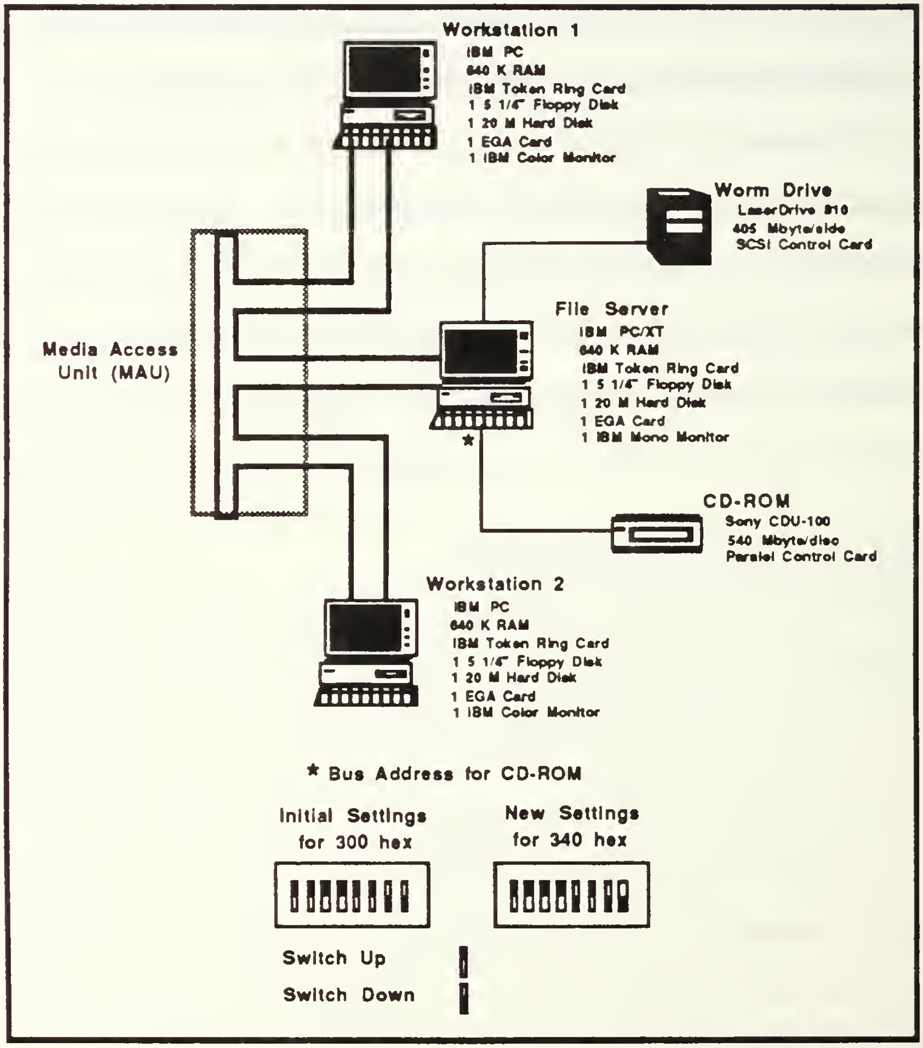


Figure 13. Token Ring Set-Up Lab Work

config.sys for File Server

```
lastdrive=z
device=ldriver.sys
buffers=10
files=100
fcbs=100,50
device=vdisk.sys
stacks=64,128
```

autoexec.bat for File Server

```
: *** Autoexec.Bat = Autoexec.TSW for Server Test System in Front Room I-158
:       Using WORM ***
ECHO OFF
: *** Provide Path to Network and DOS Programs and to Application Batch Files
:       on Hard Disk (Drive C) and to Application Programs on WORM (Drive D) ***
PATH  C:\NETWORK;C:\APPS\DOS;C:\BAT;C:\;D:\APPS;D:\;D:\BAT
ECHO ON
: *** Load Token-Ring Programs ***
TOKREUI
NETBEUI
: *** Start Server ***
NET START SRV TN7 /SRV:2 /SHR:15 /RQB:16K /USN:3 /RDR:15 /CMD:20 /SES:32
: *** Share Server Application Directory (Read Only) on Server WORM ***
NET SHARE APPS=D:\APPS /R
: *** Share Server 1DIR and Program Batch File Directories (Read,Write) ***
NET SHARE DISKE=E: /RWC
: *** Copy Program Batch Files into Vdisk E ***
XCOPY C:\BAT\*.* E:
: *** Make Vdisk E Files Read Only ***
ATTRIB +R E:\*.*
ECHO OFF
CLS
VER
: *** Access Main Network Menu ***
NET
```

Sample Application Batch File

```
: *** File name Wordper.nor
: *** Batch File for WordPerfect Test Token-Ring Network in Front Room I-158
: *** Establish path to DOS on Server (E drive), For use of WORM while using
:       Computer (C drive) and application programs on Server (E drive root) ***
path=C:\APPS\DOS;C:\APPS;D:\APPS
: *** Change directory to the WordPerfect directory on the Server (E drive)
cd  D:\APPS\wordproc\wrdperf5
: *** Switch to the C drive so that the user's output from WordPerfect will
:       go to the C drive ***
C:
: *** Use the WordPerfect command for specifying the C drive as default drive
:       and to load the WordPerfect kernel ***
D:WP/D-C:/R
: *** Change to root of application directory (D drive) so that it is set
:       correctly for next use of WordPerfect ***
cd D:\
: *** Change to standard user screen (E drive) ***
E:
: *** Reset path so that it is available after using WordPerfect ***
path=C:\APPS\dos;C:\network;D:\;C:\
```

Figure 14. WORM Installation Files

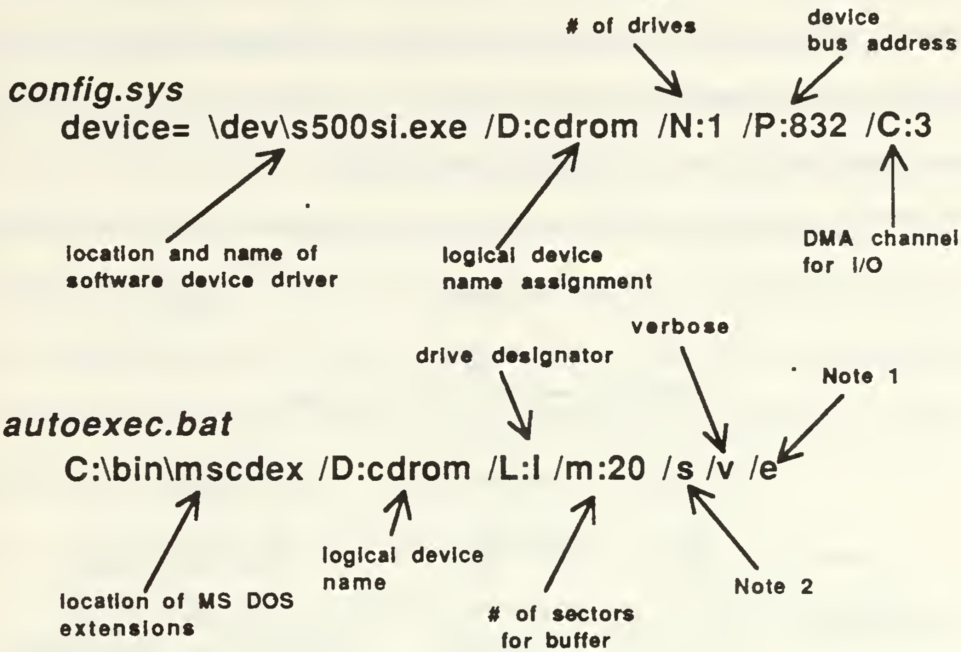
config.sys for File Server

```
lastdrive=z
device=\dev\S500SI.EXE  /D:CDROM  /N:1  /P:832  /C:3
buffers=10
files=100
fcbs=100,50
device=vdisk.sys
stacks=64,128
```

autoexec.bat for File Server

```
: *** Autoexec.Bat = Autoexec.TST for Server Test System in Front Room I-158
ECHO OFF
: *** Provide Path to Network and DOS Programs and to Program Batch Files ***
PATH  C:\NETWORK;C:\APPS\DOS;C:\BAT;C:\
ECHO ON
: *** Load Token-Ring Programs ***
TOKREUI
NETBEUI
: *** Start Server ***
 NET START SRV TN7 /SRV:2 /SHR:15 /RQB:16K /USN:3 /RDR:15 /CMD:20 /SES:32
: *** Share Server Printer (with Print Out Separator Pages) ***
 NET SHARE PRINT=LPT1
 NET SEPARATOR LPT1
: *** Share Server Application Directory (Read Only) ***
 NET SHARE APPS=C:\APPS /R
: *** Share Server Program Batch File Directories (Read,Write) ***
 NET SHARE DISKD=D: /RWC
: *** Copy Program Batch Files Into Vdisk D ***
XCOPY  C:\BAT\server\*.bat  D:
: *** Make Vdisk D Files Read Only ***
ATTRIB +R  D:\*.*
ECHO OFF
CLS
:*** Install Microsoft DOS CD-ROM Extensions to allow the File
:       Server to access the CD-ROM.  NOTE:  This will not allow
:       the CD-ROM to be shared across the LAN.
\BIN\MSCDEX.EXE  /D:CDROM  /E  /L:L  /M:10  /V  /S
: *** Access Main Network Menu ***
:NET
```

Figure 15. CD-ROM Installation Files



Note 1: This parameter will tell MSCDEX to use expanded memory if it is installed and available.
2: This parameter directs MSCDEX to patch DOS to allow CD-ROM drives to be shared on MS-NET based file servers.

Figure 16. MS-DOS CD-ROM Extensions Installation

D. APPLICATIONS USED

Throughout the testing five different applications were installed on the file server and the WORM drive: Supercalc, Dbase III plus, Wordperfect 5.0, Wordstar 5.0 and Quattro. Initial tests were conducted with these applications installed on the shared fixed disk drive of the file server. A standard file structure was used on the server Winchester disk drive and the WORM (see Figure 17). All applications were started from batch files present on a virtual disk.

Applications run from CD-ROM included *Computer Library* and *SCLSI Data Bases*. *Computer Library* was selected because it uses a popular retrieval software (BlueFish Searchware). *SCLSI Data Base* was selected because of potential future use within the DON.

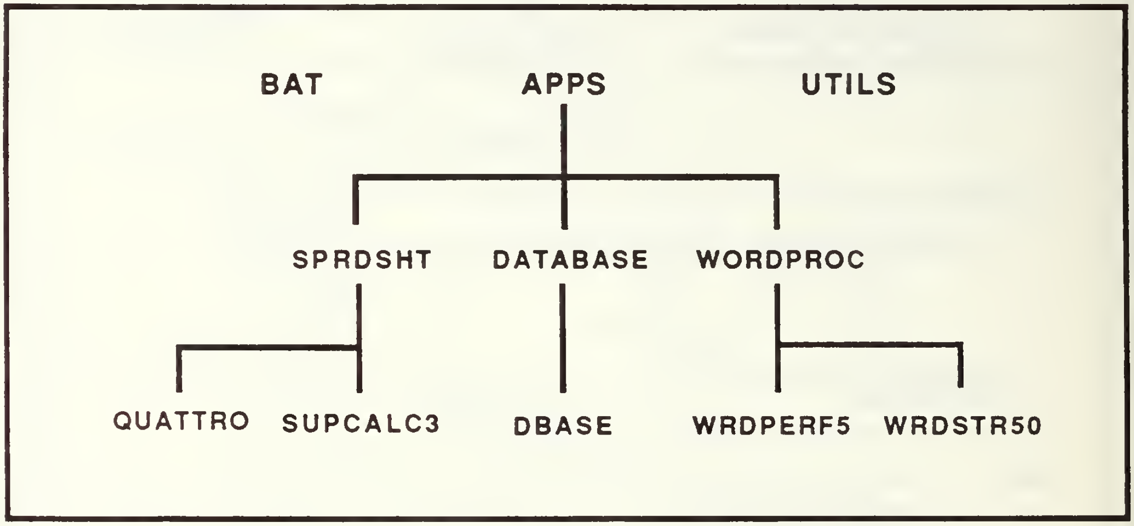


Figure 17. WORM Directory Structure

E. WORM LAB TESTS

1. Preliminary Tests Conducted on PC/XT

To provide a baseline for evaluation of system performance, all applications were executed from a Winchester disk drive on the file server with no unnecessary software present. No shells or accessory programs (such as *1dir* or *Sidekick*) were utilized and the only device drivers installed were those which are intrinsic to MS-DOS (ie., the WORM was not installed). This was done to ensure that the maximum amount of free RAM would be available for testing (no expanded memory was used in any testing). All applications executed without modification or limitation.

The next step was to modify the *config.sys* to include the number of open files and buffers which would be used with the LAN. Again all applications ran as advertised. Additional functions were added until the system RAM was reduced to the same amount that would be available to the PC without the LAN or other application software executing. This included establishment of a virtual disk, installation of the WORM device driver and adjusting the number of file control blocks (fcb). All applications were executed using batch control files (a sample of one of these batch files appears in Figure 14).

2. Test of File Server with WORM Drive

The testing of the WORM drive was accomplished in the same manner as the testing of the Winchester disk drive on the PC/XT. Unnecessary device drivers, such as the device driver for the CD-ROM, were not installed. MS-DOS CD-ROM extensions were unnecessary and were not installed (as mentioned earlier the 32 megabyte restriction was circumvented by using a 6,144 byte sector size). File control blocks (FCB) and buffers were established upon start-up with the *config.sys* as shown in Figure 14.

The file directory structure setup was identical to that used on the PC/XT's Winchester disk drive. All applications were loaded into contiguous space on the WORM. Tests conducted at this point were simply to prove that the WORM drive was operable and that the WORM device driver itself did not lead to any operational problems. All applications were

successfully executed with load and execute times comparable to those experienced on the Winchester drive.

3. Test of LAN with File Server

The WORM device driver was removed and the Token Ring LAN was then started on the file server. All functions were as noted in the previous section. The start-up of the LAN imposed severe memory restrictions on the file server (which was anticipated, see Table 5). The majority of the server's memory is dedicated to supporting the LAN and the server would no longer support applications requiring 256 kilobytes or more of RAM. This is not a restriction but rather a characteristic of most file servers. A file server performs administrative tasks and controls access to server installed peripheral devices.

The two workstations were then similarly encumbered (with the exception that the workstations did not require file server software, nor the WORM device driver). The *config.sys* and the *start.bat* files used to start the workstation on the LAN are shown in Figure 14 and the memory requirements are listed in Table 10. The WORM drive was not installed and only the file server's Winchester drive and virtual memory were shared with the workstations. All software (with the exception of *Quattro* which had an out of memory error) was then successfully loaded and executed from remote workstations. The failure to run *Quattro* was due to the amount of overhead required to operate a workstation using *IBM PC/LAN* software. *Quattro* requires a full 512 kilobytes to execute.

4. Test of LAN with WORM Drive

The LAN was shutdown and the PC/XT was re-booted with the WORM drive installed. The batch files used to load and execute the installed applications were modified to support execution from the WORM drive and the LAN was restarted. The Laserdrive 810 supports the MS-DOS file sharing utilities and the drive was made available to network users. The workstations were now restarted on the network and the USE command was utilized to establish a network path to the WORM drive. The batch files used to load and execute the installed applications were also made available to both workstations and all five applications were loaded and executed once again. As was the case with the Winchester drive, all applications (with the exception of *Quattro*) executed without modification.

TABLE 10. RAM REQUIREMENTS FOR LAB

RAM Limiter	RAM Required
MS-DOS, ver 3.2	44,656 bytes
MS-DOS extensions, ver 2.10	35,968 bytes
WORM device driver, ldriver.sys	7,558 bytes
CD-ROM device driver, s500sl.exe	9,552 bytes
PC-LAN server, ver 1.1	263,360 bytes
PC-LAN workstation, msg, ver 1.1	196,976 bytes
Virtual Disk 64 kbyte	66,304 bytes
TOKREUI	7,120 bytes
NETBEUI	46,960 bytes
stacks = 64,128	7,472 bytes
fcbs = 100, 50	5,088 bytes
buffers = 10	4,224 bytes
files = 100	4,880 bytes
last_drive = z	1,696 bytes

The WORM drive was then tested to determine the effects of simultaneous access on access time. The same five applications were used. The first test included 50 trials (10 per application) executed by the workstations from the file server's Winchester disk drive with no other users on the Token Ring LAN. An additional 25 trials were executed with simultaneous access by the two workstations. The simultaneous access was forced by executing the batch files utilized to load and run the applications from both workstations simultaneously. There was no way to guarantee that both batch files executed at precisely the same time but both workstations were observed to be retrieving the applications from the Winchester drive at the same time and thus both workstations were sharing WORM access and simultaneous disk access did exist for the majority of the load and execution sequence. The users would then alternate using the LAN until one or both of them finished the requested data transfer. All system parameters and set up were held constant so that any differences in execution time could be directly attributed to a slow down in throughput caused by multiple access of the same application files.

The identical applications were installed on the WORM drive and the LAN was restarted with the WORM connected to the file server as a shared device. Batch file modifications were limited to changing path designations to allow accessing the applications from the WORM drive. The earlier experiments were repeated by loading and starting each application (via the batch file) from the WORM drive with no other users for 50 trials. An additional twenty five trials were then performed using load

and execution with simultaneous access. Once again the differences in time could be attributed to network throughput and shared device access times.

Average load and execution times were used exclusively to determine the percentage change in times between applications executed from a fixed medium disk drive and applications executed from a WORM drive. Actual comparisons in load and execution times for a hard disk and a WORM are introduced only to show how the percentage increase in transfer time changed when contention was introduced on the two types of devices. In depth evaluation of the two medium using various file sizes and amounts of fragmentation is left for future research. The majority of time required to load and execute is directly attributable to the time required to assemble packets and pass the applications across the network coupled with the number of seeks and the latency time associated with each drive. Actual access time will vary depending on the size of the fixed drive and the buffer sizes used for each. One unexpected result was that the WORM drive showed slightly better performance than the Winchester drive. This occurred because of the non standard sector size (6,144 bytes) used by the WORM drive. The WORM also requires the maximum allowable buffer size parameter for the buffers established in the config.sys. For any large file (greater than the sector size of the Winchester drive or 512 bytes), the WORM required fewer seeks and the slow access time (relative to the Winchester drives) had little effect on data transfer time. The WORM's use of contiguous file space was not a significant advantage as the access time

for fragmented files would not have been significantly different due to the large sector size used by the WORM. Recall that the sector size is the smallest block of data which is written to a disk. The twelve to one ratio between seeks for a Winchester drive using 512 byte sector and the WORM drive using 6,144 bytes per sector would have reduced the two to one advantage in Winchester drive seek time. The results of contention tests conducted are shown in Table 11.

TABLE 11. TIME TRIALS FOR WORM DRIVE

Server Only Trials	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
User Computer 1						
DBASE III+	45.6 sec	44.5 sec	45.7 sec	46.5 sec	46.5 sec	45.8 sec
* QUATTRO	45.1 sec	48.6 sec	49.0 sec	45.9 sec	46.9 sec	47.1 sec
SUPERCALC	25.6 sec	26.9 sec	25.5 sec	26.5 sec	26.0 sec	26.1 sec
WORD PERFECT 5.0	27.9 sec	28.4 sec	27.9 sec	28.5 sec	28.4 sec	28.2 sec
WORDSTAR 5.0	30.6 sec	30.5 sec	31.6 sec	30.8 sec	30.5 sec	30.8 sec
User Computer 2						
DBASE III+	45.7 sec	46.3 sec	45.3 sec	44.3 sec	45.9 sec	45.5 sec
* QUATTRO	45.6 sec	46.3 sec	44.5 sec	46.6 sec	45.3 sec	45.6 sec
SUPERCALC	26.0 sec	25.9 sec	26.1 sec	26.0 sec	26.2 sec	26.0 sec
WORD PERFECT 5.0	28.4 sec	28.5 sec	28.1 sec	28.3 sec	28.0 sec	28.2 sec
WORDSTAR 5.0	32.8 sec	30.8 sec	30.5 sec	32.1 sec	31.7 sec	31.6 sec
Both/Exec w/Simultaneous Access						
DBASE III+	62.5 sec	62.5 sec	62.6 sec	63.6 sec	61.7 sec	62.6 sec
* QUATTRO	68.6 sec	65.7 sec	68.3 sec	67.2 sec	65.7 sec	67.1 sec
SUPERCALC	39.3 sec	37.7 sec	38.5 sec	38.4 sec	38.4 sec	38.5 sec
WORD PERFECT 5.0	40.6 sec	39.4 sec	37.5 sec	39.3 sec	39.0 sec	39.1 sec
WORDSTAR 5.0	47.8 sec	47.5 sec	48.6 sec	48.1 sec	46.5 sec	47.7 sec
Server/WORM Trials	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
User Computer 1						
DBASE III+	21.6 sec	21.6 sec	20.8 sec	21.3 sec	21.1 sec	21.3 sec
* QUATTRO	21.7 sec	21.5 sec	21.0 sec	21.3 sec	21.1 sec	21.3 sec
SUPERCALC	29.6 sec	27.8 sec	27.4 sec	26.9 sec	26.5 sec	27.6 sec
WORD PERFECT 5.0	29.2 sec	29.2 sec	28.8 sec	27.8 sec	28.7 sec	28.8 sec
WORDSTAR 5.0	26.9 sec	25.8 sec	25.6 sec	25.5 sec	24.7 sec	25.7 sec
User Computer 2						
DBASE III+	21.7 sec	20.2 sec	21.4 sec	20.0 sec	21.5 sec	20.9 sec
* QUATTRO	27.5 sec	27.3 sec	24.1 sec	23.9 sec	24.0 sec	25.4 sec
SUPERCALC	30.3 sec	26.6 sec	29.2 sec	26.7 sec	25.8 sec	27.7 sec
WORD PERFECT 5.0	27.9 sec	27.6 sec	29.4 sec	28.8 sec	29.3 sec	28.6 sec
WORDSTAR 5.0	26.1 sec	26.1 sec	26.2 sec	26.4 sec	25.9 sec	26.1 sec
Both/Exec w/Simultaneous Access						
DBASE III+	28.6 sec	28.7 sec	29.4 sec	29.2 sec	29.0 sec	29.0 sec
* QUATTRO	65.5 sec	63.6 sec	64.3 sec	65.7 sec	65.4 sec	64.9 sec
SUPERCALC	44.0 sec	42.8 sec	41.3 sec	41.9 sec	41.5 sec	42.3 sec
WORD PERFECT 5.0	42.6 sec	43.7 sec	41.9 sec	41.9 sec	42.1 sec	42.4 sec
WORDSTAR 5.0	38.0 sec	39.6 sec	39.4 sec	37.7 sec	38.2 sec	38.6 sec

TABLE 11. TIME TRIALS FOR WORM DRIVE (CONT)

	Average Time without WORM/Independent	Average Time without WORM/Simultaneous	Percent Difference
DBASE III+	45.6 sec	62.6 sec	37.20%
* QUATTRO	46.4 sec	67.1 sec	44.70%
SUPERCALC	26.1 sec	38.5 sec	47.53%
WORD PERFECT 5	28.2 sec	39.1 sec	38.66%
WORDSTAR 5.0	31.2 sec	47.7 sec	52.89%
	Average Time with WORM/Independent	Average Time with WORM/Simultaneous	Percent Difference
DBASE III+	21.1 sec	29.0 sec	37.34%
* QUATTRO	23.4 sec	64.9 sec	177.98%
SUPERCALC	27.7 sec	42.3 sec	52.87%
WORD PERFECT 5	28.7 sec	42.4 sec	48.04%
WORDSTAR 5.0	25.9 sec	38.6 sec	48.84%
* NOTE:	QUATTRO returned a low memory error and then aborted.		
	Times reflected are from initiation until receipt of the		

F. CD-ROM LAB TESTS

1. Preliminary Tests Conducted on PC/XT

To provide a baseline for evaluation of system performance, the CD-ROM was installed on the PC/XT with no (non required) software present. To ensure that the maximum amount of free RAM would be available for testing no shells or accessory programs (such as *1dir* or *Sidekick*) were utilized and the only device drivers installed were those which are intrinsic to MS-DOS plus the driver required for the CD-ROM. It

was also necessary to install the MS-DOS CD-ROM extensions. Both discs (*Computer Library* and the SCLSI disc) were accessible from the microcomputer. All search and retrieval software executed properly.

The next step was to modify the *config.sys* to include the number of open files and buffers which would be used with the LAN. Additional RAM functions were added until the system RAM was reduced to the same amount that would be available to the PC without the LAN or other application software executing. This included establishing a virtual disk and setting the number of file control blocks (fcb). Again both discs were accessible from the PC/XT.

Tests conducted to this point were simply to prove that the CD-ROM drive was operable and that the CD-ROM device driver itself did not lead to any operational problems.

2. Test of LAN with File Server

Initial attempts to start the LAN led to a program conflict error. The MS-DOS CD-ROM extensions were installed prior to the start of the LAN. When starting the network, both the Token Ring initialization (*TOKREUI*) and the NETBIOS installation were completed successfully but an attempt to start the PC-LAN operating system failed. The documentation package for the MS-DOS CD-ROM extensions indicated that such conflicts could occur and recommended installation of the extensions **after** LAN start-up. In addition it is mandatory from the PC LAN program standpoint, that it be loaded prior to any other software to ensure successful start up of the network. The system was re-booted and the

Token Ring LAN was started on the file server using the *autoexec.bat* shown in Figure 15. Starting the LAN prior to installation of the extensions was successful and the CD-ROM was accessible from the file server. All programs in RAM were as noted in the previous section. The start-up of the LAN imposed severe memory restrictions on the file server (which was anticipated, see Table 5). The majority of the server's memory is dedicated to supporting the LAN and the server would no longer support applications requiring 256 kilobytes or more of RAM. Attempts to access the data bases on the two discs led to inconsistent results:

- Running *Computer Library* led to an insufficient memory error.
- The SCLSI disc has all files saved in a DBase III+ format. DBase III+ (which is not resident on the CD-ROM) could be executed with the limited memory available on the file server. It was possible to access the SCLSI disc but only limited use was possible. Opening of multiple data bases was not possible.

As previously mentioned, these results were not surprising and the restricted memory on the file server was expected to have no effect upon execution from a remote workstation.

3. Test of LAN with CD-ROM Drive

The first major problems occurred upon attempting to share the CD-ROM drive across the network. The attempt led to an obscure error "Unable to share a Network Device". The PC/LAN technical manual provided no clarification for this error. Subsequent attempts included:

- Using the ASSIGN function which is available with MS-DOS to make the system believe that the CD-ROM was a magnetic storage device. Doing this, it was possible to access the CD-ROM drive but attempts to read the disc failed (due to the

significant differences between a magnetic device and a CD-ROM (discussed in Section IV.E.1).

- Using the ASSIGN function as noted above and installing the MS-DOS CD-ROM extensions on the workstations and attempting to access the CD-ROM remotely. This led to complete failure as the MS-DOS CD-ROM extensions were not passed across the net (or if they were they were not properly sent to the device driver on the file server).

The MS-DOS CD-ROM extensions documentation alluded to problems with the way that PC-LAN manages peripheral devices. IBM stated that their PC-LAN program does not support CD-ROM. Further investigation showed that the PC-LAN network operating system (NOS) was intercepting all remote device requests and performing a function similar to MS-DOS. The NOS was converting remote device requests into service calls (primitives) and was subsequently passing these primitives across the network. Upon receipt of the packets at the file server, the NOS passed the primitives to the CD-ROM device driver for execution. This method of device handling will not work if the primitives do not match those required to access the device. A review of the primitives shown in Table 3 will show that there are significant differences between standard service calls and those that the MS-DOS CD-ROM extensions pass to a CD-ROM device driver. There are several methods which **could** allow CD-ROM use on an IBM PC-LAN. These solutions include:

- Extending the PC/LAN NOS in much the same way as the CD-ROM extensions expand MS-DOS. This requires not only additional service calls but also, the NOS will have to be able to recognize when a CD-ROM is installed (because application

software uses standard file calls and should not have to know what type of storage device is being accessed).

- Modify the NOS so that interrupts are passed across the network as interrupts instead of service calls. The NOS could then pass the interrupts to the MS-DOS CD-ROM extension on the file server and access could occur as described in section II.D.2. This is the method used by Artisoft in Lantastic.

- Place a modified device driver for the CD-ROM on the workstation. This requires that MS-DOS CD-ROM extensions be present on the workstation and the system would have to recognize the CD-ROM as a local vice remote device. When the application passes a file access request (via an interrupt), the MS-DOS CD-ROM extensions check to see whether the device is local or remote. Because the device is thought to be a local device, the extensions process the interrupt and passes primitives to the modified device driver. The device driver utilizes the NETBIOS to transfer the primitives to the file server. The file server then passes the primitives to the CD-ROM control card where CD-ROM access occurs[5].

A number of vendors have introduced solutions which will allow CD-ROM usage on a PC-LAN network. Several of these were introduced in Section VI.D.3.c.

G. SUMMARY

Few problems were experienced installing the Laserdrive 810 WORM drive on a LAN. Due to significant differences from one WORM drive to another, however, no generalization can be made. How well a particular drive will work is highly dependent upon the device driver and whether or not it will support the SHARE command provided by MS-DOS.

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[5] This is believed to be the method used by both Meridian and OnLine for the CD-ROM connection software.

If the LAN being used requires special (non MS-DOS) device drivers, then the availability of the correct device driver will determine usefulness on the LAN.

Installation of a CD-ROM on a LAN is highly dependent upon the NOS that is used. The reason for this is that a CD-ROM bears little similarity to magnetic storage devices. WORM and Erasable drives operate similarly and can respond to the basic MS-DOS primitives (which are also supported by the NOS). The main purpose of the lab work was to prove that optical storage devices can be used as shared resources in Local Area Networks. Fine distinctions in LAN effectiveness using different devices are outside the scope of this lab work.

VIII. CONCLUSIONS/RECOMMENDATIONS

Optical storage is becoming more popular and may eventually overtake less durable data storage and retrieval mediums. Optical storage has provided an order of magnitude increase in data storage at a cost of less than double the cost of large mass storage devices. Five years ago only large corporations, universities and researchers had access to data measured in gigabytes. Now any user can have that much storage resident on his/her desk top. Current problems associated with information gathering, storage and use include:

- How to control Information costs (vice hardware costs)?
- How to control access to the massive quantities of data that are available. (Even in small organizations with ten or fewer micro-computers.)

Issues involved with implementing network technology have not been addressed. The addition of optical storage devices to an existing network environment were evaluated in an effort to isolate the "optical" issues from the "LAN" issues. The inclusion of an optical storage device further complicates an environment by requiring a significant modification to the operating system. This can impact directly on an organization because: 1) the vendor can no longer be held accountable for his own bugs; 2) updates of the operating system may not work in a modified operating system. Navy policy discourages such changes. The amount of modification required is determined by the type of optical device being installed.

- Erasable drives share most format characteristics with magnetic fixed disks. The device drivers will respond to standard MS-DOS primitives and thus should be usable in a LAN. Articles published in various periodicals support this finding. [Refs. 14 & 23]

- WORM drive characteristics vary significantly from one manufacturer to the next but most drives share format characteristics with magnetic fixed disks. Ease of installation in a LAN will be determined by the device driver. If the device driver will support the SHARE MS-DOS command then installation should be straightforward. The installation of a LaserDrive WORM drive led to no identifiable conflicts.

- CD-ROM drives are much different than the magnetic storage devices that are generally used as shared devices in LAN. The installation of a CD-ROM will require the use of MS-DOS extensions or some other MS-DOS replacement (to overcome the 32 megabyte barrier and to allow applications to take advantage of the unique features of a CD-ROM). The use of MS-DOS extensions is covered in section VI.D.3.a. [Ref. 7]. Until vendor operating systems are modified to allow for CD-ROM connection, many LAN installations will require additional hardware or software.

1. The use of optical storage devices as shared access devices in Local Area Networks is possible and highly recommended with a number of limitations.

- Workstation and file server RAM are the limiting factors to effective use of these devices. PC's with less than 640 Kbytes of RAM are inadequate for most applications.

- Use of Optical Storage devices need not be expensive. If the requirements are for a minimal network which is MicroSoft Net-based, then the use of MS-DOS extensions is probably sufficient to support requirements. If the applications require multiple volume assignment, then a more expensive solution is provided by a number of vendors.

2. To evaluate an organization's requirements for placing optical storage devices on a LAN, the following steps are recommended:

(a) Determine the organization's data requirements. Evaluate these requirements to determine whether optical storage devices are required for data access. If the organization subscribes to any of the 200+ CD-ROM data-bases go to the next step.

(b) Determine the frequency with which optical data-bases are used. How many users are likely to require access to the information simultaneously? If simultaneous access is required then go to step d.

(c) Where are the frequent users located? Is there a significant amount of distance between users or could a workstation be placed in a common area? If the distance between users is significant, are the user workstations part of the same LAN? If they are not part of the same LAN, independent optical workstations should be considered.

(d) Is a LAN available for connecting the optical storage device? If a LAN is not being used, then a review of Appendix A is recommended. Appendix A provides a cost analysis for several Optical LAN solutions. If a LAN is available then go to step e.

(e) What network hardware and software is being used by the organization? If the organization has vendor support for installed LANs then discuss shared optical devices with their technical personnel. If the organization does not have vendor support then the optical LAN solutions reviewed in Section VI.D.3.c might be appropriate.

(f) Recall that optical storage devices used as shared resources on LAN is a fairly recent development. The solutions listed in Section VI.D.3.c are not all encompassing. Additional development is expected to occur and many more solutions will become available as the technology continues to mature.

3. The use of Optical Storage is still a young technology. When this thesis was started most networks could support WORM installation but

very few Networks could take advantage of CD-ROM technology. Microsoft's release of MS-DOS extensions version 2.10 is an indication that software solutions will not be reserved for the PS/2 series of microcomputers. As this thesis is completed, at least four other vendors (Meridian, Online, Corel and Optisys) have released products specifically designed to support LAN usage of optical storage devices. Additional packages will appear based upon users demand.

4. Use of WORM drives in Local Area Networks depends upon how closely the drive primitives match the primitives utilized by fixed disk drives. One example is the Laserdrive Model 810 which was tested. The device driver for the Model 810 leads the operating system to believe that all memory is erasable. This simplifies connection of the drive into a LAN but makes MS-DOS commands such as CHKDSK inaccurate and misleading. CHKDSK will advise how much space is available in the File Allocation Table. In actuality the space remaining on the cartridge will be less than this if any files have been rewritten or deleted. To overcome these problems several utilities are included with the WORM drive to provide such services. If applications rely upon any of the MS-DOS services which are no longer available then problems may occur. In the case of the Model 810, all MS-DOS commands covered in the "COMMAND.SYS" file are properly supported. [Ref. 21]

Note that few references were made to the use of Optical Storage Devices on Macintosh Networks. Local area networks are available that support both types of computers but (except for straight data

access) there are significant differences in graphics and operating system capabilities between them. No system solution supporting both computer systems to access the same Optical Storage Device were available for testing. This fact coupled with the governments adoption of the PC as a standard made the PC world a more appropriate area of concentration. However, this may be changing as evidenced by the announcement of a huge purchase of Macintosh computers by the Air Force to do everything from word processing to command and control functions.

APPENDIX A COST DETERMINATION

A. INTRODUCTION

It is beyond the scope of this thesis to determine the value of the information which is commercially available on optical disc. The value and usefulness of information is too difficult to quantify and regardless of the database, it's value will vary not only between organizations but between users. This appendix addresses a more reasonable task of comparing the cost of installing optical storage devices in a LAN as compared to the cost of installing optical devices at each workstation. Differences between the various types of optical storage requires that CD-ROM solutions be addressed separately.

B. COST OF CD-ROM LAN IMPLEMENTATION

The economic evaluation that follows was taken in part from the Premier Issue of CD-ROM EndUser [Ref. 24] and compares three LAN solutions which have worked for connecting CD-ROM to LAN (see Table 12). The cost of similar components is listed only once and is necessary only to provide the reader with some estimate of total start-up cost.

1. Network Cost

The network cost assumes that the user owns the PC's which will be connected but that no LAN hardware or software has been installed. All figures are based upon the use of twisted pair cabling and includes sufficient hardware to establish a five, ten or twenty station LAN.

TABLE 12. CD-ROM LAN COST COMPARISON

5 USERS

	Artisoft	Meridian	Online
Network Hardware	$ 995.00	$ 1,975.00	$ 1,975.00
Network Software	$ 295.00	$ 2,995.00	$ 2,995.00
Software Drivers	$ N/A	$ 4,195.00	$ 795.00
CD-ROM Drive(s)	$ 679.00*	$ 00.00**	$ 820.00
CD-ROM Extensions	$ 00.00	$ 250.00	$ 250.00
Total	$ 1,969.00	$ 9,415.00	$ 6,835.00

10 USERS

	Artisoft	Meridian	Online
Network Hardware	$ 1,990.00	$ 3,950.00	$ 3,950.00
Network Software	$ 295.00	$ 2,995.00	$ 2,995.00
Software Drivers	$ N/A	$ 4,195.00	$ 1,495.00
CD-ROM Drive(s)	$ 679.00*	$ 00.00**	$ 820.00
CD-ROM Extensions	$ 00.00	$ 475.00	$ 500.00
Total	$ 2,964.00	$11,615.00	$ 9,760.00

20 USERS

	Artisoft	Meridian	Online
Network Hardware	$ 3,980.00	$ 7,900.00	$ 7,900.00
Network Software	$ 295.00	$ 2,995.00	$ 2,995.00
Software Drivers	$ N/A	$ 4,195.00	$ 1,495.00
CD-ROM Drive(s)	$ 679.00*	$ 00.00**	$ 820.00
CD-ROM Extensions	$ 00.00	$ 950.00	$ 1,000.00
Total	$ 4,954.00	$16,040.00	$14,210.00

Source: CD-ROM EndUser, v.1, n.3, p.60, March 1989

2. Hardware

The required hardware includes network interface cards, twisted pair wiring and other hardware which is required to set up a LAN with a shared optical drive. Hardware for Meridian and Online includes a CPU which is dedicated to CD-ROM support. The cost of the optical drive (a CD-ROM drive) is included for completeness.

3. Software

The three solutions listed use very different methods for accessing CD-ROM through a LAN. Artisoft passes DOS interrupts across the network and thus will support CD-ROM installation using MS-DOS extensions with no other CD-ROM specific software (other than the device driver) required. Only one copy of MS-DOS extensions is required for the Artisoft LAN (resident on the workstation which are sharing the drive). The solutions offered by Meridian and Online require a pseudo device driver as well as MS-DOS extensions to be resident on each workstation. For additional information concerning LAN strategies for CD-ROM see section VII.D.3. [Refs. 24, 25, 26, 27]

C. COST OF CD-ROM ADDITION TO EXISTING LAN

Cost comparisons assume that a LAN already exists and that file servers and workstations have sufficient expansion capability to support a CD-ROM drive..

1. Network Cost

The network cost assumes that the user owns the PC's which will be connected and that LAN hardware or software has been installed. .

2. Hardware

The required hardware includes CD-ROM controller cards, CD-ROM driver and connecting cables. Additional hardware costs listed are because both Optilan and Meridian solutions rely upon additional hardware. Both solutions add an additional processor/disk drive (PC) combination to handle the interface chores. Artisoft (because of its handling of interrupts) requires no additional hardware.

3. Software

Artisoft passes DOS interrupts across the network and thus will support CD-ROM installation using MS-DOS extensions with no other CD-ROM specific software (other than the device driver) required. Only one copy of MS-DOS extensions is required for the Artisoft LAN (resident on the workstation which is sharing the drive). The solutions offered by Meridian and Online require MS-DOS extensions to be resident on each workstation as well as a pseudo device driver. For additional information concerning LAN strategies for CD-ROM see section VII.D.3.

D. WORM AND ERASABLE DRIVES

The costs associated with connecting WORM or erasable drives to LANs are much easier to quantify and can easily be derived without involved calculations. The only problem anticipated with these devices is the availability (and flexibility) of the device driver associated with the

specific drive. Additional hardware (other than the controller card and the drive itself) should not be necessary for erasable disk drives. Alternate solutions may be required to install the WORM drive if the networking software has a large administrative overhead. An example of this is Novell's Netware. Netware has a built in security feature wherein duplicate directories are maintained to protect stored data. These extra directories are intended to be temporary but will (of course) become permanent on a WORM drive. If the shared WORM is used frequently, even it's huge storage capacity could be inadequate requiring frequent replacement of the drive cartridge. Corel and Optisys have introduced products which allow duplicate directories on magnetic disk thus providing the security features of netware without the disadvantages of writing additional information to the WORM.

GLOSSARY

Note: Glossary definitions extracted from *Computer Library*, August Issue, copyright *The Computer Language Company Inc. 1989*. [Ref. 28] unless otherwise noted.

absolute address. An absolute address, or machine address, is the explicit identification of a peripheral device, of a location within the peripheral device or of a location in memory. ...The computer must be given absolute addresses to reference its memory and peripherals.

access time--The time required to find, retrieve, and display a piece of recorded information. Access time usually refers to the longest time a storage device requires to get to a piece of information. For man CD-ROM drives, access times range from 0.5 to 1.5 seconds. [Ref. 29]

address An address is the number of a particular memory or peripheral storage location. ...

address bus. An address bus is an internal channel from the processor to memory across which the addresses of data are transmitted. The number of lines (wires) in the address bus determine the amount of memory that can be directly addressed as each line carries one bit of the address. For example, the Intel 8086/8088 processors have 20 address bus lines and can address up to 1,048,576 bytes of memory.

archival storage. Archival storage is backup or long-term storage of data in machine readable form.

ASCII (American Standard Code for Information Interchange). ASCII, is a binary code for data that is used extensively in communications, in most minicomputers and in all personal computers. ASCII was originally a 7-bit code allowing 128 possible character combinations, the first 32 of which are used for communications and printing control purposes. ...

AUTOEXEC.BAT (AUTOmatic EXECute BATch file). AUTOEXEC.BAT is a Microsoft DOS file that, if present on disk, is executed immediately when the computer is started (booted). ...

base address. The base address is the location in memory where the beginning of a program is stored. The relative address from the instruction in the program is added to the base address to derive the absolute address. ...

BIOS (Basic Input Output System). A BIOS is a set of routines that contain the detailed instructions for activating the peripheral devices connected to the computer. In IBM personal computers, the BIOS resides in a read only memory (ROM) chip and accepts requests for input and output from both the operating system and the application programs. Since many popular software packages send requests to the BIOS directly, all compatible computers must also have a compatible BIOS. The "autostart" routine in the BIOS is responsible for testing memory upon startup and preparing the computer for operation. It searches for BIOS components that are located on the plug-in boards and sets up pointers in main memory to access them.

bit (BInary digit). A bit is single digit in a binary number (1 or 0). ... The most common storage unit is the byte, which is made up of eight bits and is equivalent to one alphanumeric character. ...

bits per second. See BPS.

block. (1) On magnetic disk and tape, a block is a group of records that is stored and transferred as a single unit. (2) In communications, a block is a contiguous group of bits or characters that is transmitted as a unit.

BPI (Bits Per Inch). BPI measures the number of bits stored in a linear inch of a track on a recording surface, such as on a disk or tape.

BPS (Bits Per Second). BPS measures the speed of data transfer.

buffer. A buffer is memory reserved to hold something temporarily. In a program, buffers are reserved areas of RAM that hold data while it's being processed. A buffer may be physically a specified part of the computer's general memory pool (RAM) as declared by the program, or it may be special memory set aside for a single purpose. ...

byte. A byte is the common unit of computer storage from personal computers to mainframes. A byte holds the equivalent of a single character, such as the letter A, a dollar sign or decimal point. ...

CAV--Constant *Angular* Velocity. A technique that spins a disc at a constant speed, resulting in the inner disc tracks passing the read/write head more slowly than the outer tracks. This results in numerous tracks forming concentric circles with the storage density being the greatest on the inner track. [Ref. 1]

CD-ROM (Compact Disc Read Only Memory). CD-ROM is a CD (compact disc) format that is used to hold data (text and pictures) as well as audio. The disc has the same physical appearance of a music CD disc, but tracks used for holding data use different size sectors than tracks used for high-fidelity audio. ...Like other peripheral devices connected to a personal computer, a CD-ROM player is cabled to and controlled by a controller card (printed circuit board) that is plugged into one of the personal computer's expansion slots. ...

CD-ROM Extensions. CD-ROM Extensions are the software required to use a CD-ROM player in an IBM compatible pc using Microsoft's DOS operating system. It is made up of two software modules, (1) a driver that is specialized for the CD player by its manufacturer and, (2) a RAM resident program...supplied by Microsoft, which is executed when the computer is turned on. ...

central processing unit. See CPU.

cluster... A cluster is a group of disk sectors that is treated as a single entity.

CLV--Constant *Linear* Velocity (see CAV). Used with CD-ROM to keep the data moving past the optical head at a constant rate. In order to accomplish this, the rotational speed of the disc must vary, decreasing as the head moves from the inner tracks toward the outer perimeter. The range is approximately 500 to 200 rpm for a CD-ROM disc drive. [Ref. 1]

command. A command is an action statement or order to the computer. Commands are language statements which are part of any software package that offers choices and accepts user input. ...

command language. A command language is a special-purpose language that accepts a limited number of commands, such as a query language, job control language (JCL) or command processor.

COMMAND.COM. COMMAND.COM is a command processor for Microsoft's DOS operating system ... COMMAND.COM creates the user interface by displaying the screen prompts, accepting the typed-in commands and executing them. Other command processors, or shell programs, can be substituted for COMMAND.COM in order to provide a different way of commanding the operating system.

compact disc. See CD-ROM.

CPU (Central Processing Unit). The CPU, also called the central processor, or simply processor, is the computing part of the computer. It is made up of the control unit and arithmetic/logic unit. The control unit extracts the instructions out of memory and executes them. ...

cross-interleaved Reed-Solomon Code--The first level of error correction used in CD-ROM and the only error correction needed for CD Digital Audio. Use of CIRC yields an error rate of one uncorrectable error per $10^{=9}$ bytes. Further error detection and correction in CD-ROM systems improve this to one error per 10^{-13} bytes.

CSMA/CD (Carrier Sense Multiple Access/Collision Detection). CSMA/CD is a baseband communications access method that uses a collision-detection technique. When a device wants to gain access onto the network, it checks to see if the network is free. If it isn't, it waits a random amount of time before retrying. If the network is free and two devices attempt to gain access at exactly the same time, they both back off to avoid a collision and each wait a random amount of time before retrying.

data bus. A data bus is an internal pathway across which data is transferred to and from the processor. Controllers for peripheral

devices, such as monitors and disks, are printed circuit boards that plug into the computer's data bus.

data rate. The data rate is the measurement of the speed of data transmission within a computer or communications network.

defacto standard. A defacto standard is a format or language that is widely used and copied, but has not been officially sanctioned by a standards organization, such as the American National Standards Institute (ISO). ...

device. A device is any electronic or electromechanical machine or component, from as small as a transistor to as large as a peripheral unit, such as a magnetic tape or disk drive. Device always refers to hardware; for example, a device driver refers to the software that activates the hardware.

device address. See address.

device control character. In communications, a device control character is a special code that activates some function on a terminal.

device driver. See driver.

device independent. Device independent refers to keeping the detailed instructions for activating a peripheral device in the operating system and explicitly out of the application programs. With device independence, an application program can run in many different computer systems, each using different kinds of devices. ...

device name. A device name is a name assigned to a hardware device that represents its physical address. For example, **a:** is a device name.

direct access. Direct access is the ability to go directly to a specific storage location without having go through what's in front of it. Memories and disks are the major direct access devices. Memories hold data in sequentially numbered bytes, and disks hold data in sequentially numbered sectors. ...

disk operating system. See DOS.

DMA (Direct Memory Access). DMA is a specialized microprocessor that transfers data from memory to memory directly without using the main processor, although it may periodically steal cycles from it. The DMA technique moves data faster than by passing it through the processor.

DOS (Disk Operating System). DOS may refer to any computer operating system from microcomputer to mainframe. However, for personal computers, it usually refers to the operating system used in IBM compatible pcs, known as DOS, PC-DOS or MS-DOS. ...

driver. (1) A driver, or device driver, is a program routine that contains the instructions necessary to control the operation of a peripheral device. Drivers contain the detailed knowledge about the unique properties of the devices they manage, for example, the number of sectors per disk track or the number of lines of screen resolution. They contain the precise machine language and codes necessary to activate all the functions of each device. ...The operating system requires a driver for every peripheral device attached to it. Drivers normally come with the operating system, but, with personal computers, there is such a proliferation of hardware enhancements that the operating system does not support every device on the market. In these cases, drivers are supplied by the maker of the device or by the vendor of the application software...

Ethernet. Ethernet is a local area network developed by Xerox, Digital and Intel that interconnects personal computers via coaxial cable. It uses the CSMA/CD access method and transmits at 10 megabits per second. Ethernet uses a bus topology that can connect up to 1,024 personal computers and workstations within each main branch. Ethernet has evolved into the IEEE 802.3 standard.

external interrupt. An external interrupt is an interrupt caused by an external source such as the computer operator, external sensor or monitoring device, or another computer.

FAT (File Allocation Table). A FAT is a map of disk space in Microsoft's DOS and OS/2 operating systems that keeps track of current used, unused and damaged sectors. The FAT is replicated twice on each

disk volume. The directory, which contains file ID, such as name, extension and date of last update, points to the FAT, which contains the actual sector locations for the file.

file server. A file server is a computer in a local area network that stores the programs and data files shared by the users connected to the network. A file server acts like a remote disk drive to the users in the network. A file server is also called a network server.

fixed disk. A fixed disk is a non-removable disk system such as is found in most personal computers...

format. ... A disk format is the layout of the storage units of a disk. Before data can be recorded (written) on a disk, a format program must be used to break up the disk into recording segments, called sectors. The format program records the sector numbers on the disk which are used to identify the sectors from then on.

giga. Giga means billion, and is abbreviated as "G." For example, 10 Gbytes is 10 billion bytes; ...

hardware. Hardware is machinery or equipment, such as a CPU, video terminal, disk drive and printer. ...Contrast with software, which is the set of instructions that tell the computer what to do. ...

head crash. A head crash is the physical destruction of a hard disk. Due to head misalignment or contamination with dust and dirt particles, the read/write head collides with the disk's magnetic coated recording surface. The recorded data is destroyed, and both the disk platter and read/write head usually have to be replaced...

High Sierra Group--An ad hoc working group of CD-ROM service companies, vendors, and manufacturers which has been a prime source of activity in the setting of standards for CD-ROM data format and compatibility. The group was named after its first meeting place--the High Sierra Hotel at Lake Tahoe. [Ref. 1]

IEEE (Institute of Electrical and Electronic Engineers). IEEE is a membership organization that includes engineers, scientists and students in electronics and allied fields. ...The IEEE is involved with setting standards for the computer and communications field. ...

IEEE 802.3. 802.3 is a standard for a local area network that uses the CSMA/CD access method (OSI layer 1). This standard has been popularized by the Ethernet local area network.

IEEE 802.5. 802.5 is a standard for a local area network that uses a token passing ring access method (OSI layer 1).

Index. (1) In data management, an index is a directory of the location of records and files on a disk. Indexing is the most common method used for keeping track of data on a disk or other direct access storage device, such as a drum or optical disk (CD-ROM). An index of files contains an entry for each file name and its location. An index of records has an entry for each key field, for example, account number, and its location. The indexes are maintained by the operating system or database management system whenever data is retrieved or updated.

input/output. See I/O.

input/output controller. Same as peripheral controller.

instruction. An instruction is a command to the computer. The term usually refers to machine language instructions that only the computer understands. However, it may also refer to a command statement in a programming language or software package. ...

interrupt. An interrupt is a hardware feature that signals the CPU that an input or output is required. For example, keystrokes and mouse movement generate an interrupt. An instruction in the application program generates an interrupt when it's time to input or output some data. Networks also generate interrupt signals that the computer must respond to. When an interrupt occurs, control is transferred to the operating system, which determines what action should be taken. ...

interrupt-driven. Interrupt-driven refers to a computer or communications network that uses interrupts.

I/O (Input/Output). An I/O is a transfer of data between the CPU and a peripheral device. Every transfer is an output from one device and an input into another.

KB. (KiloByte or KiloBit) KB stands for one thousand bytes or bits.

land--The reflective area between two adjacent non-reflective pits disc. The transition from pit to land or land to pit represents a binary 1. [Ref. 1]

laser (Light Amplification from the Stimulated Emission of Radiation). Lasers generate a very uniform light that can be precisely focused. They are used in a wide variety of applications, such as communications, electrophotographic printing and optical disk (CD-ROM) storage...

local area network. A local area network is a communications network that serves several users within a confined geographical area. Although the term may refer to any communications network within a building or plant, it typically refers to the interconnection of personal computers...

machine language. ...All computers have machine language that cause it to INPUT from and provide OUTPUT to peripheral devices and communication channels. ...In addition, there are instructions that test and control peripheral devices. For example, an instruction can check the status of a disk to see if it is ready to read or write. Another instruction causes the access arm to go to (seek) a specific track...

mag tape. See magnetic tape.

magnetic disk. Magnetic disks are direct access storage devices that are the primary storage medium used with computers for fast access to programs and data. ...The disk surface is divided up into several circular tracks that are concentric (circles within circles). ... The circular tracks are further divided into segments, called sectors, which determine the least amount of data that can be read or written (recorded) at one time...Hard disks ... rotate typically from 2,400 to 3,600 revolutions per minute and are constantly spinning after being turned on... Floppy disk speed is typically 300 revolutions per minute, 10 times as slow as hard disks...

magnetic tape. Magnetic tapes are sequential storage devices that are primarily used for data collection, backup and historical purposes... When tapes are used for archival storage, they must be periodically

recopied. If the tape is not used for several years, the magnetic bits can contaminate each other, since the tape surfaces are tightly coiled together.

megabit. A megabit is 1,000,000 or 1,048,576 bits. It is also written as MB, Mb, Mbit and M-bit. ...

megabyte. A megabyte is 1,000,000 or 1,048,576 bytes or characters.

memory management. Memory management is the way a computer deals with its memory, which includes memory protection and any virtual memory or memory swapping techniques...

microfiche & microfilm. Microfiche & microfilm are films that contain miniaturized documents. A microfiche is a 4x6" sheet of film that holds several hundred document pages. A microfilm is a continuous film strip that can hold several thousand document pages. The documents are magnified for human viewing by specialized readers, some of which can automatically locate a particular page using various indexing techniques Microfiche & microfilm are generated by devices that take pictures of paper documents, or by COM (computer output microfilm) units that accept output directly from the computer.

micron. A micron is one millionth of a meter, which is approximately 1/25,000 of an inch.

millisecond. A millisecond is one thousandth of a second.

MS-DOS (MicroSoft-Disk Operating System). MS-DOS is the operating system from Microsoft Corporation that runs in IBM compatible personal computers. It is almost identical to the operating system that is used on the IBM personal computers, called DOS, or PC-DOS,... MS-DOS is a single user system that normally runs one program at a time. ...MS-DOS can address up to one megabyte of RAM, although only 640K is usable for application programs. The remaining 384K is used by the operating system. MS-DOS can handle up to 32 megabytes per disk drive...

NetBIOS. NetBIOS is an applications programming interface (API) which activates network operations on IBM compatible pcs running under Microsoft's DOS operating system. It is a set of network commands

that the application program issues in order to transmit and receive data to another station on the network. The commands are interpreted by a network control program or network operating system that is NetBIOS compatible.

network architecture...With regard to local area networks (LANs), network architecture refers to the various topologies, for example, bus, ring, star and tree configurations.

network operating system. A network operating system is a control program that resides in a file server within a local area network. It handles the requests for data from all the users (workstations) on the network.

open architecture. Open architecture refers to a system in which the specifications are made public in order to encourage third-party vendors to develop add-on products for it. ...

optical disk. An optical disk is a disk that is written (recorded) and read by light. ...The storage capacity of an optical disk is considerably greater than its magnetic disk counterpart for the same amount of disk surface. ...In addition, lasers can be moved electronically and don't have to be physically moved as do the read/write heads on magnetic disks and tapes.

OSI (Open System Interconnection). The OSI is a communications reference model that has been defined by the International Standards Organization (ISO). It is a seven-layer communications protocol intended as a standard for the development of communications systems worldwide...

Layers 1 and 2 are mandatory in order to transmit and receive in any communications system. Layers 3, 4 and 5 are provided by the controlling network software (network control programs and network operating systems) and have typically been treated as one layer by vendors. Layers 4, 5 and 6 are often combined into one or two layers in existing communications systems. Control is passed from one layer to the next, starting at the application layer in one station, proceeding to the bottom layer, over the communications channel to the next station and back up the hierarchy. From top to bottom, the layers of the OSI model are:

LAYER 7 - APPLICATION LAYER Layer 7 is the set of messages that application programs use to request data and services from each other. Electronic mail and query languages are examples of this layer.

LAYER 6 - PRESENTATION LAYER Layer 6 is used to convert one data format to another, for example, one word processor format to another or one database format to another.

LAYER 5 - SESSION LAYER. Layer 5 establishes and terminates the session, queues the incoming messages and is responsible for recovering from an abnormally terminated session.

LAYER 4 - TRANSPORT LAYER Layer 4 is responsible for converting messages into the structures required for transmission over the network. A high level of error recovery is also provided in this layer.

LAYER 3 - NETWORK LAYER The network layer establishes the connection between two parties that are not directly connected together. For example, this layer is the common function of the telephone system. When an X.25 packet switching network performs this function, the route that has been established from one device to another is called a virtual circuit.

LAYER 2 - DATA LINK LAYER The data link layer is responsible for gaining access to the network and transmitting the physical block of data from one device to another. It includes the error checking necessary to ensure an accurate transmission. This layer is the communications protocol that is most commonly referenced and often implies the specifications for Layer 1 as well. See "Categories of Data Link Protocols" on the following page.

LAYER 1 - PHYSICAL LAYER The physical layer defines the actual set of wires, plugs and electrical signals that connect the sending and receiving devices to the network...The RS-232 interface is a common standard for personal computers. CATEGORIES OF DATA LINK PROTOCOLS. The data link layer (layer 2 of the OSI model) is the most commonly referenced in communications because it is responsible for packaging the data for transmission and transmitting it. Packaging refers to breaking up the data into blocks of a specified length and appending codes to it for identification and error checking.

The data link protocol often includes the electrical and physical specifications (layer 1 of the OSI model) as well...

PC bus. The PC bus is the bus architecture used in first-generation IBM compatible pcs. The PC bus comes in two versions: an 8-bit bus and a 16-bit bus, the latter also known as the AT bus. 8-bit boards will fit into both 8-bit and 16-bit buses, but 16-bit boards will fit only in the 16-bit bus...

pinouts. Pinouts are the description of the function of electronic signals transmitted through each pin in a connector.

pit--The microscopic depression in the reflective surface of a disc. The pattern of pits represents the data being stored on the disc. The light from the laser used to read the data is reflected back from the lands, but scattered by the pits. A typical pit is about the size of a bacteria - 0.5 by 2.0 microns. [Ref. 1]

program. A program is a collection of instructions that tell the computer what to do...A program is made up of (1) instructions, (2) buffers and (3) constants. Instructions are the directions that the computer will follow, and a particular sequence of instructions is called the program's logic. Buffers are reserved spaces in the program that will accept and hold the data while it's being processed. Constants are fixed values within the program that are used for comparing. The program calls for data in an input-process-output sequence. After data has been input into one of the program's buffers from a peripheral device, such as a keyboard or disk, it is processed. The results are then output to a peripheral device such as a display terminal or printer. If data has been updated, it is output back onto the disk. The application program, the program that does the organization's data processing, does not instruct the computer to do everything. When the program needs input or is ready to output some data, it sends a request to the operating system, which contains the actual instructions to perform input and output activities. The operating system performs the activity and turns control back to the application program.

program statement. A program statement is a sentence or line of instruction in a high-level programming language. One program

statement may result in several machine instructions when the program is compiled.

program step. A program step is an elementary instruction, such as a machine language instruction or an assembly language instruction...

RAM (Random Access Memory). RAM is the computer's primary working memory. It's called random access because each byte of memory can be accessed at random without regard to the adjacent byte or bytes. ...

RAM resident program. A RAM resident program is a program that stays in memory at all times. The advantage of a RAM resident program is that it's immediately usable without having to call it in from the disk...RAM resident programs are also called TSR (terminate and stay resident) programs.

random access. Same as direct access.

read/write head. A read/write head is a device that reads (senses) and writes (records) data on a magnetic disk or tape...Unlike a laser beam, which can be electronically moved, all magnetic media (disks and tapes) require movement of the recording surface past the read/write head in order to function.

ROM (Read Only Memory). A ROM is a memory chip that permanently stores instructions and data. Its contents are placed into the ROM at the time of manufacture and cannot be altered. ROMs are used extensively to hold codes and programs that are reasonably permanent.

ROM BIOS (Read Only Memory Basic Input Output System) A ROM BIOS is the part of an operating system that contains the machine instructions necessary to activate the peripheral devices...

run--The distance between transitions either from land to pit or pit to land. The distance represents two or more zeros. [Ref. 1]

SCSI (Small Computer System Interface). The SCSI is an interface standard for a personal computer that connects up to seven peripheral devices. ...The SCSI provides a high-speed, parallel data

transfer of up to four megabytes per second and has the advantage of connecting multiple peripheral units while taking up only one slot in the computer.

sector. A sector is the smallest unit of storage read or written by a disk. ...The sector is the physical unit called for by an instruction, for example, READ TRACK 17 SECTOR 23.

sector interleave. The sector interleave, or sector map, is how sectors are numbered on a hard disk. The interleave can be sequential (0,1,2,3...) or staggered, for example, 0,3,6,1,4,7,2,5,8. In sequential numbering, if data in sector 1 is read, by the time the access to 2 is given, the beginning of sector 2 has passed the head and must rotate around to come under the head again. The staggering of sectors optimizes sequential reads and writes to a disk.

seek. (1) A seek is the moving of the access arm to the requested track on a disk...

seek time. Seek time is the time it takes to move the read/write head to a particular track on a disk after the instruction has been executed. The average seek time is also called the access time.

shared resource. A shared resource is a peripheral device, such as a disk or printer, that is shared by multiple users. For example, a file server and laser printer in a local area network are shared resources.

software. Software is instructions to the computer. A series of instructions that performs a particular task is called a program or software program. The two major categories of software are system software and application software. System software is made up of control programs, such as operating systems, database management systems and network control programs. Application software is any program that processes data for the user...

spooling (Simultaneous Peripheral Operations On Line). With personal computers, spooling refers to printing a document or file in the background while allowing the user to work on something else.

Spooling originated with mainframe operations in which data on low-speed peripheral devices, such as a card reader, was transferred to disk first and then fed to the computer at high speed. Conversely,

output from the computer to a low-speed device, such as a printer, was stored on disk and then fed to the printer. Spooling is also used to transmit to and receive from remote batch terminals that transmit at low speeds. Spooling programs monitor the activity of shared peripherals and schedule their tasks based on the priority of the data that is being stored.

star network. A star network is a communications network in which all the terminals are connected to a central computer. Private Automatic Branch Exchanges (PABXs) are prime examples of a star network. Local area networks, such as IBM's Token Ring and AT&T's Starlan are also examples of a star network.

terminate and stay resident. Terminate and stay resident software issues a DOS interrupt (21h) for the 31h service. This allows the program to continue residing in memory after it has passed control back to DOS. Because it is in memory it can be activated at any time, without the delay normally associated with reading a program from a disk. [Ref. 30]

token ring network.

(1) A token ring network is a communications network that uses the token passing technology in a sequential manner. Each station in the network passes the token on to the station next to it.

(2) Token Ring network is a local area network developed by IBM that interconnects personal computers via a special cable containing twisted wire pairs. It uses the token passing access method and transmits at four megabits per second. Token Ring uses a star topology in which all computers connect to a central wiring hub, but passes tokens to each of up to 255 stations in a sequential, ring-like sequence. Token Ring conforms to the IEEE 802.5 standard and is a part of IBM's SNA strategy to interconnect all of its various computer lines.

topology. In communications networks, a topology is the pattern of interconnection between terminals and computers. For example, a star topology connects all nodes to a central system. A bus topology connects all devices to a single line. A ring topology connects devices in a circle.

track. A track is a storage channel on a disk or tape. Tracks are a series of concentric circles on disks or parallel lines on tape.

transfer time. Transfer time is the time it takes to transmit or move data from one place to another. It is the time interval between starting the transfer and the completion of the transfer.

VAR (Value Added Reseller). A VAR is an organization that adds value to a system and resells it. For example, a VAR could purchase a computer and various peripherals from different vendors and a graphics software package from another vendor and package it all together as a specialized CAD system. See OEM.

Winchester disk. A Winchester disk is a sealed disk technology that was developed by IBM, which incorporates the access arm, read/write heads and disk platters into a sealed unit. By aligning the read/write heads to their own set of disks, greater storage capacities and accessing speeds are obtainable than with removable disk cartridges... Although originally a self-contained, removable module, the term is used today to refer to any fixed hard disk.

workstation. In a local area network, workstation refers to a personal computer that serves a single user in contrast with a file server or network server, which serves all the users in the network.

LIST OF REFERENCES

1. Lind, D. J., *Optical Laser Technology, Specifically CD-ROM, and Its Application to the Storage and Retrieval of Information,* Master's Thesis, Naval Postgraduate School, Monterey, California, June 1987

2. Lai, R. S. and The Waite Group, Inc., *Writing MS-DOS Device Drivers,* pp. 18-21 Addison-Wesley Publishing Company, Inc. 1987

3. Buddine, L. and Young, E., *The Brady Guide to CD-ROM*, Prentice Hall Press, pp. 73-74, Copyright 1987

4. Lai, R. S. and The Waite Group, Inc., *Writing MS-DOS Device Drivers,* pp. 41-50 Addison-Wesley Publishing Company, Inc. 1987

5. Lai, R. S. and The Waite Group, Inc., *Writing MS-DOS Device Drivers,* pp. 72-83 Addison-Wesley Publishing Company, Inc. 1987

6. Halsall, F., *Data Communications, Computer Networks and OSI*, Second Edition, p. 533, Addison-Wesley Publishing Company, 1988

7. Derfler, F. J., Jr., "Building Workgroup Solutions: Low-Cost LANs", *PC Magazine*, v. 8, n. 6, p. 94-112 March 28, 1989

8. Glass, B., "In Detpth, PC Communications: Understanding NetBIOS", *BYTE*, pp. 301-306, January 1989

9. Adams, L. and Carlo, J., "Fiber-Optic LANS Carry Own Weight on Navy Ships", *Government Computer News*, , v.8, n.7, pp. 61-62, Ziff-Davis Publishing Company, 3 April 1989

10. Strole, Norman C., "The IBM Token Ring Network-- A Functional Overview", *IEEE Network*, v.1, n.1, pp. 23-30, January 1987

11. Stephenson, P. "Topology, Protocol Influence Most Networking Decisions", *Government Computer News*, v.8, n.7, pp. 61-63, 3 April 1989

12. Ropiequet, S., *CD-ROM Volume 2, Optical Publishing*, Microsoft Press , 1987

13. Stephenson, P., "Maximum Has a Mean, Lean Kind of WORM", *Government Computer News*, v.8, n.4, pp. 62-65, 20 February 1989

14. Stevens, L., "Erasable Technology Comes to Optical Disc", *MacWEEK*, v.3, n.18, p. 32-34, 2 May 1989

15. Williams, S. F., "CD-ROM Drives Have Become 'Friendly Peripherals' with Standardization", *PC Week*, v.5, n.31, 1 August 1988

16. Helgerson, L. W. and Martens, H. G., "In Search of CD-ROM Data", *PC Tech Journal*, v.6, n.10, pp 67-75, October 1988

17. Stevens, L., "WORM drives: Optical Storage Made Permanent", *MacWEEK*, v.3, n.18, p. 28, May 1989

18. Buddine, L. and Young, E., *The Brady Guide to CD-ROM*, Prentice Hall Press, pp. 383-394, 1987

19. Helgerson, L. W. and Meyer, F. P., "CD-ROM Publishing Strategies", *PC Tech Journal*, v.6, n.10, pp 53-63, October 1988

20. Microsoft Inc, *MS-DOS CD-ROM EXTENSIONS Product Overview and Technical Specifications,* May 1989

21. LASERDRIVE LIMITED™, *INSTALLATION and OPERATION GUIDE for the MODEL 810-11 & MODEL 810-12 OPTICAL SUBSYSTEMS*

22. Buddine, L. and Young, E., *The Brady Guide to CD-ROM*, Prentice Hall Press, pp. 393, 1987

23. Topper, A., "WORMs, EOs and Other Creatures", *LAN Times*, v.6, n.1, pp.43-45, January 1989

24. Ennis, M. G., "Tech Talk; CD-ROM on LAN", *CD-ROM EndUser*, v.1, n.1, pp.59-61, March 1989

25. Williams, S. F., "Networking Extensions Help Solve Problems with Multiple Access to Data", *PC Week*, v.5, n.31, p. 52, 1 August 1988

26. Kim, G., "Networked CD-ROMs", *LAN Times*, v.6, n.1, pp. 45-49, January 1989

27. Shafer, R., "Product Watch: LANtastic", *PC Tech Journal*, v.7, n.4, pp. 113-115, April 1989

28. *Computer Library*, August Issue, copyright *The Computer Language Company Inc. 1989.*

29. *Ropiequet, S., CD-ROM Volume 2, Optical Publishing*, Microsoft Press , p. 301, 1987

30. Lai, R. S. and The Waite Group, Inc., *Writing MS-DOS Device Drivers*, Addison-Wesley Publishing Company, Inc., p. 187, 1987

BIBLIOGRAPHY

Adams, L. and Carlo, J., "Fiber-Optic LANS Carry Own Weight on Navy Ships", *Government Computer News*, , v.8, n.7, 3 April 1989

Anderson, J., "Systems Perspective, Succeeding at CD-ROM", *PC Tech Journal*, v.6, n.10, pp. 9-10, October 1988

Berry, P., *Operating the IBM PC Networks* , SYBEX Inc, 1986

Buddine, L. and Young, E., *The Brady Guide to CD-ROM*, Prentice Hall Press, 1987

Cassano, A. J., "CD-ROM: An Alternative Logistics Data Distribution Medium", Prepared for Naval Supply Systems Command, 18 April 1989

Cassano, A. J., "NAVSUP CD-ROM Initiative", *Navy Supply Corps Newsletter*, May/June 1989

Computer Library, August Issue, copyright *The Computer Language Company Inc. 1989.*

Connor, D., "CSMA/CD Party Line", *LAN TIMES*, v. VI, i. VI, June 1989

Cowan, L., "National Archives Test Optical Storage", *Government Computer News*, v.8, n.3, 6 February 1989

Derfler, F. J. Jr., "A Field Guide to LAN Operating Systems", *PC Magazine*, v.7, n.11, pp.117-150, 14 June 1988

Derfler, F. J., Jr., "Building Workgroup Solutions: Low-Cost LANs", *PC Magazine*, v. 8, n. 6, p. 94-112, 28 March 1989

Dixon, R.C., "Lore of the Token Ring", *IEEE Network*, v.1 n.1, January 1987

Dortch, M., "A Storage Media Primer", *LAN Times*, v.6 n.1 pp.38-39, January 1989

Ennis, M. G., "Tech Talk; CD-ROM on LAN", *CD-ROM EndUser*, v.1, n.1, March 1989

Frentzen, J., "Commercial CD-ROM Titles", *CD-ROM Review*, v.3 n.9, December 1988

Glass, B., "In Detpth, PC Communications: Understanding NetBIOS", *BYTE*, pp. 301-306, January 1989

Halsall, F., *Data Communications, Computer Networks and OSI*, Second Edition, Addison-Wesley Publishing Company, 1988

Helgerson, L. W. and Martens, H. G., "In Search of CD-ROM Data", *PC Tech Journal*, v.6, n.10, pp 67-75, October 1988

Helgerson, L. W. and Meyer, F. P., "CD-ROM Publishing Strategies", *PC Tech Journal*, v.6, n.10, pp 53-63, October 1988

IEEE Computer Society, "Logical Link Control", ANSI/IEEE Standard 802.2-1985, (ISO/DIS 8802/2), IEEE 1984

IEEE Computer Society, "Token Ring Access Method and Physical Layer Specifications" ANSI/IEEE Standard 802.5-1985 (ISO/DP 8802/5), IEEE 1985

Johnson, J. S., *Adaptability and Feasibility Issues Concerning the Use of CD-ROM Technology for United States Navy Applications,* Master's Thesis, Naval Postgraduate School, Monterey, California, March 1988

Jordon, L. and Churchill, L., *Communications and Networking for the IBM PC & Compatibles, Revised and Expanded*, Brady Books, 1987

International Business Machines Corporation Entry Systems Division, *IBM Personal Computer Seminar Proceedings*, May 1985, .

International Business Machines Corporation, *IBM Token-Ring Network NETBIOS User's Guide* , Copyright 1986

Jordon, L.E. and Churchill, B., *Communications and Networking for the IBM PC & Compatibles*, Revised and Expanded, Brady Books, Simon & Schuster, Inc. 1987

Kim, G., "Networked CD-ROMs", *LAN Times*, v.6, n.1, January 1989

Lai, R. S. and The Waite Group, Inc., *Writing MS-DOS Device Drivers*, Addison-Wesley Publishing Company, Inc. 1987

LASERDRIVE LIMITED™, *INSTALLATION and OPERATION GUIDE for the MODEL 810-11 & MODEL 810-12 OPTICAL SUBSYSTEMS*

Leggott, M., "CD-ROM and LAN", *CD-ROM EndUser*, v.1, n.3, July 1989,

Lind, D. J., *Optical Laser Technology, Specifically CD-ROM, and Its Application to the Storage and Retrieval of Information,* Master's Thesis, Naval Postgraduate School, Monterey, California, June 1987

McManus, T., "Transparent CD-ROM Networks Ease Data Transfer", *Government Computer News*, v.8, n.3, 6 February 1989

Menkus, B., "Lack of Imagination Stalls Optical-Disk Applications", *Government Computer News*, v.8, n.3, 6 February 1989

Microsoft Inc, *MS-DOS CD-ROM EXTENSIONS CD-ROMifying Your Software,* March 1989

Microsoft Inc, *MS-DOS CD-ROM EXTENSIONS Function Requests Specification,* March 1989

Microsoft Inc, *MS-DOS CD-ROM EXTENSIONS Hardware-Dependent Device Driver Specification,* March 1989

Microsoft Inc, *MS-DOS CD-ROM EXTENSIONS Installation Instructions,* March 1989

Microsoft Inc, *MS-DOS CD-ROM EXTENSIONS MS-DOSifying Your CD-ROM,* March 1989

Microsoft Inc, *MS-DOS CD-ROM EXTENSIONS Networking CD-ROMS,* March 1989

Microsoft Inc, *MS-DOS CD-ROM EXTENSIONS Product Overview and Technical Specifications,* May 1989

Microsoft Inc, *MS-DOS CD-ROM EXTENSIONS Questions and Answers,* March 1989

Oren, Tim, "The CD-ROM Connection", *BYTE,* pp. 315-320, December 1988

Pitt, D., "Standards for the Token Ring", *IEEE Network*, v.1, n.1, January 1987

Ropiequet, S., *CD-ROM Volume 2, Optical Publishing*, Microsoft Press , 1987

Ross, F.E., "Rings Are 'Round for Good", *IEEE Network*, v.1, n.1, January 1987

Ruster, A., "Insufficient Standards Block Optical-Disk Connectivity", *Government Computer News*, v.8, n.3, 6 February 1989

Scheib, C. M. and Fogarty, J. S., "DOS 4.0 and MS-DOS Extensions", *CD-ROM EndUser*, v.1, n.3, July 1989

Shafer, R., "Product Watch: LANtastic", *PC Tech Journal*, v.7, n.4, pp. 113-115, April 1989

Shields, J., "Govt. Still Looking for a Great LAN", *Government Computer News*, v.8, n.10, 15 May 1989

Silberschatz, A and Peterson J.L., *Operating Systems Concepts*, Alternate Edition, Addison-Wesley Publishing Company, 1988

Simpson, D., "Is Write Once the Right Choice", *Systems Integration*, May 1989

Stephenson, P., "Maximum Has a Mean, Lean Kind of WORM", *Government Computer News*, v.8, n.4, 20 February 1989

Stephenson, P., "Micro Network Operating Systems", *Government Computer News*, v. 8, n.9, 1 May 1989

Stephenson, P. "Topology, Protocol Influence Most Networking Decisions", *Government Computer News*, v.8, n.7, 3 April 1989

Stevens, L., "WORM drives: Optical storage made permanent", *MacWEEK*, v.3, n.182, May 1989

Stevens, L., "Erasable Technology Comes to Optical Disc", *MacWEEK*, v.3, n.18, 2 May 1989

Strole, Norman C., "The IBM Token Ring Network-- A Functional Overview", *IEEE Network*, v.1, n.1, January 1987

Topper, A., "WORMs, EOs and Other Creatures", *LAN Times*, v.6, n.1 pp.43-45, January 1989

Weisenberger, P., "Army Sheds Pounds of Paperwork by Using ODI", *Government Computer News*, v.8, n.3, 6 February 1989

Willett, M., "Token-Ring Local Area Networks--An Introdution", *IEEE Network*, v.1, n.1, January 1987

Williams, S. F., "CD-ROM Drives Have Become 'Friendly Peripherals' with Standardization", *PC Week*, v.5, n.31, 1 August 1988

Williams, S. F., "Networking Extensions Help Solve Problems with Multiple Access to Data", *PC Week*, v.5, n.31, 1 August 1988

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